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ROY WALDO MINER

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*Executive Director:* EUNICE THOMAS MINER

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## *SECTION OF GEOLOGY AND MINERALOGY*

# GEOLOGY OF THE BUILDING STONES OF ANCIENT GREECE*

*By* Norman Herz

*Boston, Mass.*

### *Introduction*

Alpine tectonics have largely determined the strike of formational changes in Greece (Renz, 1947). The structural trend is north-south in northern Greece, parallel to the Dinaric Alps. Further south, in the region of Thessaly, the strike swings eastward toward Asia Minor. The *Zwischengebirge* consists of crystalline basement rocks in Attica and the Cyclades Islands. This Attic-Cycladic massif of marbles, gneisses, schists, and granitic intrusives has been dated as pre-Cambrian by Lepsius (1893), pre-Carboniferous, probably Siluro-Devonian, by Renz (1947), and Triassic by Kober (1929). In Attica, these rocks are overlain by an overthrust mass of Cretaceous rocks, largely limestones. West and southwest of this massif, in Boeotia and the Argolide, lies the East Hellenic Zone with a series of very low-grade metamorphic rocks including serpentine, slate, chert, and limestone, of Jurassic to lower Cretaceous age and with a structure somewhat complicated by nappes. These two areas supplied the principal sources for building stones used in the Athenian Agora.

The Agora excavations, in Athens, are probably the most important archaeological excavations in progress today in Greece, from the points of view both of historic interest and of total effort expended. The rocks used by the classical Greeks in the Agora of Athens for both building and statuary were the primary ones studied by the author in 1951-1952.

All the building stones of pre-Roman times, except for Cycladic marbles used in the Athenian Agora, appear to have been quarried in Attica or its vicinity (Herz, 1952). The Attic stones are from the crystalline series and include the Hymettian and Pentelic marbles, the largely unmetamorphosed but cataclastically deformed Cretaceous Acropolis and Eleusinian limestones, and unmetamorphosed Tertiary beds. These Tertiary beds comprise two facies, one developed in shallow marine waters, the "πῶρος" (poros) stone of Piraeus and Aegina, and the fresh water Kara limestone and conglomerate from the west slopes of Mount Hymettus.

*This paper, illustrated with lantern slides, was presented at a meeting of the Section on April 4, 1955.

The author wishes to express his gratitude to J. H. Hartshorn for critically reading the manuscript; to Penelope Hanshaw for drafting the map; and to his wife, Rhoda Herz, for assisting in the carbonate analyses.

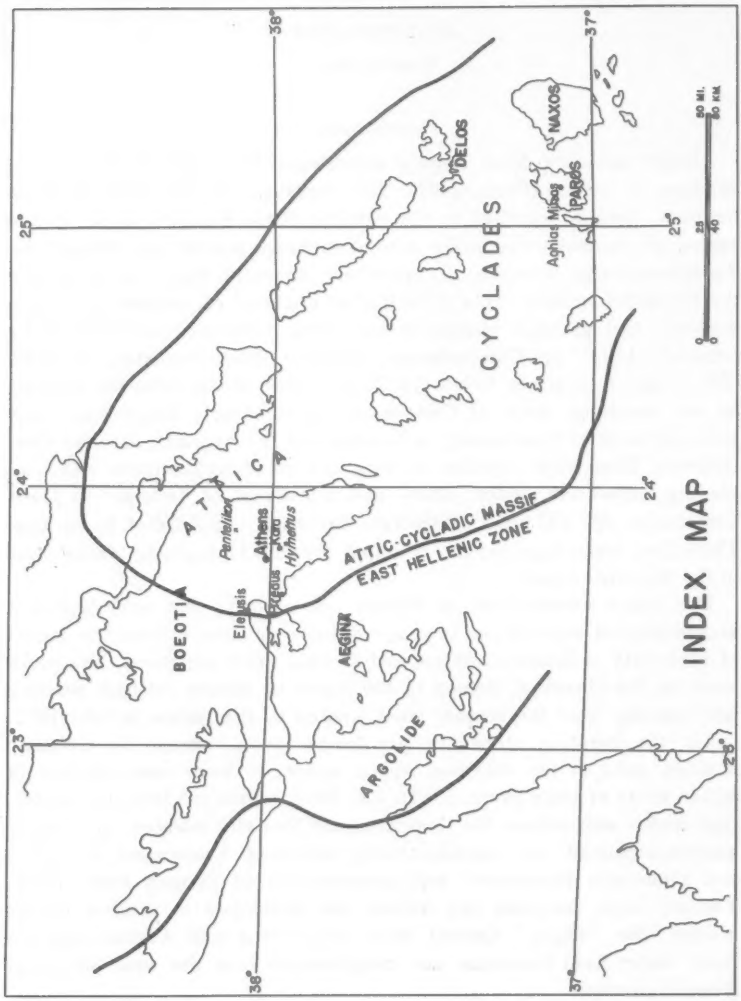
INDEX MAP
ATTIC-CYCLADIC MASSIF
EAST HELLENIC ZONE
ATTICA
BOEOTIA
CYCLADES
ARGOLIDE
ARGINA
DELOS
NAXOS
PAROS
Aghios Mylos
Athens
Eleusis
Pentelikon
Hymettus
Kara
Aegina
38°
37°
25°
24°
23°
50 MI.
50 KM.

FIGURE 1

### *Cretaceous Rocks*

*Acropolis limestone.* The Acropolis limestone type locality is the rock platform of the Acropolis. Outcrops of this limestone continue on the hills to the south and southwest. The rock is a medium bluish-gray to light gray limestone, though often reddish-brown to pale red, especially when brecciated. A similar limestone was quarried on Lycabettus and is quarried today at Turkovuni.

The greater part of this formation is intensely brecciated. It is generally a very tough rock, with a conchoidal fracture, and well bedded with evidence of movement along the bedding planes. Crystallinity is sometimes developed to a very low degree in the brecciated pieces, but generally their component grains cannot be made out with a hand lens. The dimensions of these pieces are variable, but the cementing material which may be coarsely crystallized is dominantly carbonate, chiefly mixtures of calcite, dolomite, and ankerite. The rock will fracture through both the cement and matrix unless the cement grains are exceptionally large or friable. The Acropolis limestone is a difficult stone to work because of its frequent lack of planes of weakness, and its conchoidal fracture. This inherent toughness, however, makes it ideal as foundations and for use in walls.

*Eleusinian limestone.* The type locality for the Eleusinian limestone is along the north slope of the hill of Eleusis. The classical site itself is built into the east slope of the same hill. The color of this rock varies in shades of reddish-brown and also from medium light gray to medium dark gray, and thus much darker than the gray varieties of Acropolis limestone. Like this gray variety, Eleusinian limestone is also largely brecciated. Modern quarries exist all along the hill and have obliterated traces of the ancient workings.

The rock is structurally and petrographically similar to the Acropolis limestone, but has little tendency towards a conchoidal fracture. A stone similar to the Eleusinian limestone, although slightly lighter in tone, was found at Aegina, outcropping in the temple area, and at Daphne. Both, probably, were quarried and used locally.

### *Tertiary Rocks*

*"Poros."* The marls and limestones of Aegina and Piraeus, "poros" stone, represent a Tertiary transgression of the sea over part of Attica (Charalambakis, 1951). Most of the deposits are sandy and argillaceous, indicating, together with their fauna, that they must have formed in shallow coastal and brackish waters. Fresh-water limestones were deposited about the same time further inland in Attica, as at Kara and the south slope of Mount Pentelikon.

The type locality for the "poros" in Piraeus is on the Akte peninsula, hence the ancient's name, "*ακτίης λίθος.*" The ancient quarries disap-

peared with the building up of the port, though modern quarries are still operating along the northwest slope of the Akte hill, and the stone crops out in many unpaved streets. On Aegina, an ancient working can be found about two kilometers due north of the town. The stone can be obtained in many other places in the northern third of the island, however, and must have been worked at least for local needs.

The Piraeus formation consists largely of alternating marls and limestones, from one half meter up to two meters in thickness. Resistance to erosion varies from beds that are almost soluble in water to tough calcilutites. The color ranges from yellowish gray to white (TABLE 1).

The limestones and marls of Aegina are similar to those of Piraeus and, indeed, are identical geologically (TABLE 1). Oolitic limestones, however, appear to be more abundant on Aegina.

TABLE 1

ANALYSES OF "POROS"

| *Type* | *Insolubles* | *Bulk spec. grav.* | *Resistance* |
|---|---|---|---|
| *Piraeus stones* | | | |
| Calcilutite | 0.3-0.9%, clay | 2.16-2.41 | High |
| Marly limestone | 5.2%, clay | 2.70 | High |
| Coquina limestone | 5.5- 7%, sand | 2.03-2.12 | Low |
| Marl | 15-65%, clay | Variable | Friable |
| *Aegina stones* | | | |
| Calcilutite | 1.3-2.3%, clay | 2.25-2.56 | High |
| Marly limestone | 6.9%, clay | | High |
| Oolitic limestone | 0.9-4.2%, clay | 2.03-2.35 | Friable |
| Marl | ~ 50%, clay | Variable | Friable |

The Tertiary limestones and marls were used very extensively in foundations in the ancient Agora. From analyses of blocks used in the Stoa of Zeus, located on the west side of the Agora excavations (TABLE 2), it was determined that only certain beds were used, probably those that could be worked most easily. These beds included calcilutites, limey marls, and marl limestones. When exposed to the atmosphere, some marls readily fall apart, but when confined in foundations in the dry Attic soil, they hold together fairly well. The calcilutites, of course, are resistant irrespective of their position.

TABLE 2

"POROS" BLOCKS FROM THE STOA OF ZEUS, AGORA EXCAVATIONS, ATHENS

| *Type* | *Insolubles* | *Resistance* |
|---|---|---|
| Calcilutite | 1.2%, clay | High |
| Limey marl | 33.3-37.3%, sand and clay | High |
| Marly limestone | 15.1-19.4%, clay | Friable |

*Kara limestone.* The Kara limestone was deposited in fresh-water lakes and was quarried by the ancients at Kara–the modern Helioupolis–although it can also be found in other places in Attica. Many small, modern quarries existed in the area between Pentelikon and Hymettus, as near Amaroussion and Pikermi, and also further to the south, near Chasani.

The limestone is always associated with Tertiary conglomerate, into which it passes gradationally. The color varies from light yellowish gray to shades of moderate pink. It is a tough rock, very resistant, with a well defined conchoidal fracture, and often approximates lithologic limestone. It is generally dense but, in cavities and fractures, calcite may develop with crystals up to one cm. Banded travertine is common, as are porous varieties, with abundant fossils, but both these are also hard and tough.

The Kara limestone is more difficult to work than marble, because of its dense grain fabric and tendency to split in almost any direction. It is a tougher stone, however, because of this dense fabric, and never becomes friable upon exposure, as marble often does. It could thus be used equally well in foundations, columns, and other parts of buildings.

*Conglomerate.* Throughout Attica, in Tertiary times, rapidly flowing streams coursing down the slopes of Hymettus and other hills deposited a conglomerate. The conglomerate is exposed today in many stream channels leading away from the west slope of Hymettus, and must have been quarried in ancient times in some of these channels. Abundant conglomerate can be found in the area of the ancient Kara limestone quarries where, perhaps, the first quarrying of the stone was attempted. The conglomerate, because of its cement, is usually of a reddish color, and includes elliptical pebbles up to 25 cm. long. The pebbles are of banded or white marbles, schist, Cretaceous limestones, and vein quartz. The conglomerate is easily worked and, although not very resistant, suffices for foundations.

### *Crystalline Rocks*

*Introduction.* The marble used by the classical Greeks has been discussed by the author in recent publications (Herz and Pritchett, 1953; Herz, 1955), and so only a brief summary will be given here.

Archaeologists know when marble was quarried at different sites in ancient times in Greece. Most of the early marble came from the island of Naxos and was quarried on the island's north and northeast coast. These quarries were later abandoned when a beautiful translucent marble, the "lychnites" or lamp marble, was found on the island of Paros, near the modern Aghias Minas. This Parian marble was used throughout classical times for statuary purposes and was mined in a bed that is only three meters thick and dips 35°. As a building stone,

it was supplanted by marble from Mount Pentelikon in Attica, quarried during the Golden Age of Athens, and used for such famous temples as the Parthenon. Finally, during Roman times, marble was quarried on Mount Hymettus, in Attica. Since the dates of operation of each area are well known, it behooves the geologist to provide the necessary clues for distinguishing the marbles. If this were done, then a powerful tool would be provided for dating temples and statuary that have not yet been dated by archaeological methods. Present methods do not suffice. This fact has been demonstrated, for instance, by three epigraphers, agreeing on the rock type of only one inscription out of 29 (Herz and Pritchett, 1953, TABLES 1 to 3).

No simple test has yet been demonstrated to differentiate unequivocally the ancient Greek marbles. Fabric studies appear to offer the most promise (Weiss, 1954; Herz, 1955), and may eventually provide the solution for many perplexing archaeological problems.

*Attic marble.* The marble found on Mounts Pentelikon and Hymettus includes five general types: (1) marble breccias and mylonized marbles; (2) schistose marbles; (3) dolomitic marbles; (4) white, medium-course grained marble, aesthetic "Pentelic"; and (5) banded marbles, aesthetic "Hymettian." The type locality for the Pentelic is the ancient quarry of the Spilia Daveli on the south slope of Mount Pentelikon. Foliation is well developed by grain elongation and sometimes by muscovite and chlorite. Grain size alternates in bands from coarse, .6 × .8 mm., to fine-medium grained.

The type localities for the Hymettian are the Roman quarries along the west side of Kakorhevma on Mount Hymettus. Alternating white or light gray and bluish bands ranging from a few millimeters to a few centimeters in thickness give the rock its banded character. The grain size tends to be finer than Pentelic, ranging largely through fine and medium, and the rock has more mylonized bands.

*Island marble.* Compared to Attic marble, Parian marble, or lychnites, is a pure crystalline marble with rare accessory minerals. Its grain size is commonly one to two mm., though also about one half mm., and with a foliation that can be seen only in polished or thin sections. Lychnites is translucent through 35 mm. (Lepsius, 1890), whereas the best Pentelic is translucent only through about 15 mm. Naxian marbles also lack a clearly visible foliation plane, but are coarse to granular, not particularly translucent, and often banded. Marble similar to Naxian is also found on the islands of Delos and Paros and may have been exploited there and used locally.

## *Conclusion*

There is a definite need for more work in the field of geology as applied to classical archaeology. The application of scientific techniques

to the history of man will certainly result in a better appreciation and understanding of man's heritage. That result is justification enough for any field of research.

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## *SECTION OF PHYSICS AND CHEMISTRY*

# INVESTIGATIONS IN THE BIOPHYSICS AND BIOCHEMISTRY OF THE CELL NUCLEUS*

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Because it will not be possible to review adequately all of the work in this field in the space at my disposal, I shall limit this presentation to describing two series of my own experiments. The first of these, dealing with the response of nuclei and chromosomes to ionizing radiations, falls in the field of biophysics, while the second series is biochemical. As we shall see later, the results of the two kinds of experiments complement each other in yielding information about the nucleus, the chromosomes, and the genes.

Ionizing radiations at low doses produce microscopically detectable, localized changes in chromosomes without destroying or seriously altering the immediate viability of the cells treated. By analyzing the response of chromosomes to such radiations, one might hope to get some information about their structure. In the cycle of changes of the nucleus and of its chromosomes, certain stages, identifiable with the microscope, have been designated. These are: the prophase, the metaphase, the anaphase, the telophase, and the interphase. The prophase is characterized by the visible shortening and thickening of the chromosomes. The metaphase and anaphase are the stages in which the nuclear membrane disappears and the new chromosomes are separated. In the telophase stage, the separated groups of chromosomes are reconstituted into nuclei. This stage is followed by one of long duration, the interphase, during which no microscopically visible changes have been detected. The chromosomes could be seen to be doubled in the prophase, but the time of their separation at the submicroscopic level was not known. Obviously, synthesis of the new chromosomes would have had to occur prior to the stage when they became separated.

In somatic or mitotic divisions, the changes in phase of the nuclei of the various cells of a tissue are not synchronized but, in the reduction divisions of some plants and animals, such synchronization does occur, and one may take advantage of this situation to determine the relative sensitivity to radiation of the different stages. In plants of the genus *Gasteria*, the stages found to be most sensitive to X rays were those at the end of the interphase of the premeiotic division and the pachytene stage of meiosis. The same result was obtained with plants of another genus, *Vicia*. In both cases, the log per cent of chromosomes remaining

*This paper, illustrated with lantern slides, was presented at a meeting of the Section on April 5, 1955.

unaltered was a linear function of the dose, giving what have been called one-hit survival curves on the sensitive volume or target hypothesis. In *Gasteria*, the length of the chromonemata could be obtained by applying the equation for the helix, since the coiling was regular, but in *Vicia* it was irregular. Coiling was regular in the somatic chromosomes of *Vicia*, however, and subsequent experiments showed that the sensitivity to X rays and to neutrons was quantitatively the same for chromosomes in the pachytene stage of meiosis as it was for those at the end of the mitotic interphase.[1,2,3,4] When somatic tissues were irradiated, it was found that the mitotic process was arrested at the end of the interphase at a stage which was designated as the onset of the prophase. The curves for the frequency of abnormalities with time paralleled those for the inhibition of mitosis, the maximum inhibition and the maximum abnormalities appearing at three hours after irradiation. Thus, the cells examined at three hours after irradiation were known to have been in the onset of prophase at the time of irradiation. At this stage, one-hit curves were obtained for all of the species studied and the slopes of the curves were related to the size and number of chromosomes. Those species with the longer and more numerous chromosomes had the steeper slopes. In two species, *Vicia* and *Pisum*, the chromonemata were regular helices, so that the total chromonematic length could be calculated. It was found that the ratios of the slopes of the curves were approximately equal to the ratios of the chromonematic lengths. In other words, in these two species the sensitivity was directly proportional to the chromonematic length. Treating the data which had been obtained for *Gasteria* in the same way, it was found that the approximate proportionality held for this species as well. In the other species, where measurements could not be made, rough estimates suggested that the same proportionality probably obtained in these as well. When the length of the chromonemata was taken as one dimension of the sensitive volume, the diameters in the three species where lengths could be obtained proved to be 10 to 20 Å. This suggested that, if the sensitive volume represented a real structure, its size was that of a relatively small molecule or, if it were asymmetric, that its cross-section was relatively small.[5]

Morphologically, the meiotic and mitotic processes are quite dissimilar, but the irradiation results showed that in both there was a condition of maximum sensitivity at those stages where one had reason to believe there were closely approximated structures that later became separated widely enough to be microscopically distinguishable (pachytene and the onset of prophase). The finding of maximum sensitivity at these stages suggested an analogy with the behavior of proteins and colloids that are flocculated by ionizing radiation only when they are positively charged. If the phenomena were really similar, then it could be predicted that the chromosomes would become much less sensitive to radiation if

the intracellular environment were altered so that the positively charged surfaces were made to carry a net negative charge. By treating plant root tips with solutions of ammonia during irradiation, it was found that the frequency of abnormalities observed three hours later was reduced, and that the reduction varied with the concentration. Furthermore, this effect was confined to that period when the chromosomes were most sensitive, their sensitivity at the other stages being unaltered. Since sensitivity reversal was obtained with ammonia concentrations equivalent to a pH of about 10.4, the strongly basic protamines were excluded as possible reactants, since they would have remained positively charged. Similarly, the proteins, other than the protamines and histones, were excluded, since, at the normal intracellular pH they would be on the alkaline side of their isoelectric points and would carry a net negative charge. By similar reasoning, the nucleic acids could also be excluded. Irradiation in atmospheres containing as much as 80 per cent $CO_2$ did not alter the chromosome sensitivity, possibly because the intracellular pH could not be lowered sufficiently by this means. With tobacco mosaic virus, whose isoelectric point is at pH 3.4, the response to X rays could be explored in the pH range of 2.2 to 7.0, and it was found that the sensitivity of the virus to X rays was increased at pH 3.0 and lower. Thus, wherever the tests could be performed, the results were in accord with the hypothesis that positively charged materials were involved in the X-ray response and, in the case of the chromosomes, the most likely compounds implicated were the histones. The sizes of the structures concerned, as calculated by the sensitive volume hypothesis, were in accord with the deduction that histones were involved.[6,7,8]

The uniformity in the diameters of the sensitive volumes of chromosomes of every different microscopic size indicated that the values calculated from the data were more than just probability numbers, but, from the nature of the sensitive volume hypothesis, the dimensions obtained could be considered to be only lower limits to the size of the structures involved. By irradiating tissues with neutrons of approximately 8 MEV, the ionization produced would be due very largely to protons with an average spacing of about 10 Å. between ion pairs as compared with a mean spacing of about 1,000 Å. for the 200 KV X rays used. Thus, from analysis of the results obtained with neutrons, one might expect to get an upper limit for the size of the sensitive material. The kinds of chromosome abnormalities and the frequency of abnormalities as a function of time after treatment were found to be the same as with X rays, and the percentage of the chromosomes remaining normal was again a simple exponential function of the dose. As with the X rays, the species with the larger chromosomes were more sensitive. On making comparisons with the X-ray curves, it was found that for all the species examined the ratio of the neutron to X-ray slope was approximately six in all cases where the neutron dose was measured in arbitrary "n"

units. Physical measurements showed the "n" unit to be equivalent in ionization to 2.5 roentgens.[10] Protons, therefore, were about two and one-half times as efficient as X rays. If it were assumed that clusters, rather than pairs of ions were needed, the efficiency of neutrons should have been very much larger. On the other hand, if the diameter of the sensitive portion of the chromosomes were much larger than 10 Å., the efficiency of the protons should have been much less than that of the X rays. Although the factor of two and one-half remained unaccounted for, it was possible to conclude that the upper, as well as the lower limit of the sensitive diameter was of the order of 10 Å. Furthermore, the approximate constancy of the ratios of the slopes of the neutron and X-ray survival curves supported the previous deduction that this diameter was about the same in the species studied, and extended the deduction to include those species in which the chromonematic lengths could not be measured with the microscope.[9,10]

Although the survival curves that were obtained three hours after treatment with X rays and with neutrons all gave ratios of approximately six, a very different situation was found when a similar analysis was applied to the response of a single type of cell of any one species at other time intervals. The curves were again straight lines in all cases, but the ratios of the neutron to X-ray slopes varied from 6 to 17 at time intervals ranging between 3 and 24 hours. Other experiments had shown that, in the cells studied, the average time for a complete nuclear cycle was 24 hours, and that cells which took 4 to 18 hours to reach anaphase had been in the nuclear interphase stage when irradiated. The differences in relative response showed that the conditions for nuclear response were not constant during the interphase, i. e., there were changes in intrachromosomal structure and function during this period that, microscopically, appeared to be homogeneous. It was possible, by comparison of the neutron/X-ray ratios, to identify tissues with a similar nuclear physiology even though they were in different species. Since different tissues of the same animals gave different ratio patterns, one could conclude that, in embryological development, the chromosomes do not remain the same but become altered somehow in the different tissues.[11,12,13]

In contrast to the production of chromosome abnormalities, it was found, by analysis of the response of a series of polyploids, that inhibition of mitosis by ionizing radiation occurred by action at one, or else a very few specific regions of the chromosome, and not throughout the length of the chromonemata. This inhibition occurred just prior to the submicroscopic separation of the chromonemata.[14] From the data on the abnormalities, the separation must have taken place throughout the length of the chromonemata—and these lengths are of the order of millimeters.[5] The energy of a single ion pair, or cluster, absorbed in the inhibition-sensitive regions could not conceivably, by direct action,

affect chromosome development throughout its entire length. It follows, therefore, that these regions must somehow be involved in chromosomal events, not only within themselves, but also at all the other loci of the chromosome. Other morphological evidence indicated that the centromere—probably identifiable with the regions mentioned above—was essential for the initiation of those changes that ultimately led to the separation of the chromonemata at the beginning of the prophase.[15]

The radiation data also led to other conclusions about the behavior of chromosomes. These conclusions are mentioned, as follows, only briefly:

(1) In mitosis, the pairs of newly formed chromonemata are separated at the succeeding anaphase and not at the second succeeding anaphase as had been previously postulated.[5,15]

(2) In all the types of cells studied, there was a critical stage in the synthesis of new chromosomes during the interphase which took 12 hours to reach the anaphase. This was deduced from the fact that slopes of the survival curves, plotted as a function of time after irradiation, showed a peak or plateau at this time. This stage was most pronounced in the cells of a lymphoma or lymphosarcoma.[12,13]

(3) Another stage in mitosis, which took 18 hours to reach anaphase and, therefore, was near the beginning of the interphase, was characterized by the production of half-chromatid fragments not found in nuclei irradiated at other stages.[15] Thus, at least two types of chromosomal events in the interphase could be recognized, although the nature of these events remained unknown.

(4) The data on the meiotic division showed that, at synapsis, the new chromonemata had already been synthesized but had not yet been separated. Also, they indicated that pairing at synapsis must be between faces of the chromonemata other than the ones at which the new strands are synthesized.[3]

Before leaving the radiation studies, it should be mentioned that the data obtained could not be explained either by the older theories that postulated diffusible toxins or by the more recent free radical concept. The former would require that the reaction curves show some threshold which was not found, while the latter would require an independence of concentration that was not found, *i.e.*, the more chromosomal material present per cell, the greater was the response.

With the finding of different physiological states in the interphase nucleus, it seemed that information on the chemistry of nuclei and chromosomes would be needed to explore the problem further. A simple technique for isolating nuclei was devised and, employing this method for obtaining nuclei in quantity, it became possible to investigate the metabolism of these nuclei in relation to that of the cells which contained them by injecting solutions of sodium phosphate containing $P^{32}$ into animals and later isolating nuclei and other cell fractions. Control experiments showed that in such nuclei the $P^{32}$ was chemically bound

and not adsorbed. In a nongrowing tissue, the liver, the ratio of nuclear to total tissue $P^{32}$ remained constant at all time intervals after injection while, in a tumor in the same animals, the ratio rose, at first rapidly, and then slowly throughout the period of the investigation. It was shown, by comparison of the specific activities of the $P^{32}$ in nuclei and cytoplasm, that in the tumor there must have been synthesis of nonlabile phosphorus compounds which occurred to a smaller or insignificant extent in the liver. Investigation of $P^{32}$ turnover in regenerating, as compared with normal liver, showed that the accumulation of $P^{32}$ in the nucleus was correlated with mitotic activity. When mitosis was initiated, accumulation of $P^{32}$ began and, when mitosis ceased, the nuclei no longer had the capacity for accumulating $P^{32}$. Extractions showed that, in both liver and tumor, most of the nuclear $P^{32}$ was in the lipid-free, acid-insoluble fraction, *i.e.* in the nucleoprotein. The accumulation in the tumor nuclei was expected because of the synthesis of new nuclei with growth, but this explanation would not account for the $P^{32}$ found in the nuclei of nongrowing tissue. It was concluded that in nuclei of nongrowing tissue, the nucleic acid, or portions of it, was continually being broken down and reformed.[16,17]

Knowing the rate of accumulation of $P^{32}$ and the amount of P in the nucleus, the time required for the nucleus to synthesize an amount of P-containing material equal to that originally present was 27 hours. Measurements on the growth in volume of the tumor showed that it doubled its size in about 24 hours. This was in good agreement with the results obtained with X rays, which gave values of about 24 hours for the average duration of a complete mitotic cycle.[17]

It was pointed out that the decrease in $P^{32}$ in the liver nuclei shortly after administration indicated a movement of phosphorus out of the nuclei as well as into them, and that a similar process might be taking place in the tumors but be obscured by the rapid accumulation of $P^{32}$ due to the laying down of new nucleic acid. In an attempt to obtain information in this connection, animals carrying tumors were irradiated with low doses of X rays and shortly thereafter given $P^{32}$ intravenously. The amount of $P^{32}$ taken up by liver and tumor tissue remained unaltered. In the liver, the distribution of $P^{32}$ between nuclei and cytoplasm was unchanged. In the tumor, however, there was a marked increase in the relative amount of nuclear $P^{32}$ as early as two hours after irradiation when the effect was maximal. Possible explanations of the phenomenon as being due to breakdown of nuclei or to changes in permeability could be ruled out. The absence of the phenomenon in the liver pointed to a correlation between relative increase of $P^{32}$ in the nucleus and mitotic activity. If mitosis were arrested while synthesis of new nucleic acid was not inhibited, there would be a greater proportion of cells with more nucleic acid, *i.e.*, the fraction of the population having twice, or almost twice the amount of nucleic acid found in a newly formed nucleus

would be increased.[17] This is just what would be expected if mitosis were arrested at the end of the interphase, as the previous X-ray data had shown to be the case.[5]

Continuing these experiments, it was found that repeated washing and storage of isolated nuclei in cold saline removed very little or no $P^{32}$. On incubation in saline at 37° C., however, large amounts of radioactivity were removed. The phosphorus that did come off was in combination with compounds which had absorption spectra characteristic of nucleic acids, and the ratio of the phosphorus to the extinction at 260 mμ was the same as that for ribonucleic acid. It was found that the material which came off the nuclei was not dialyzable and, therefore, probably polynucleotide rather than individual nucleotides. By adding crystalline ribonuclease, the rate of removal of the labelled nucleic acid was increased. If the nuclei were digested first with ribonuclease, and if desoxyribonuclease were added subsequently, no additional $P^{32}$ was removed, although large amounts of additional polynucleotide came off the nuclei. Evidently, in the nuclei of the normal liver, all of the $P^{32}$ was in the ribonucleic acid (RNA) and not in the DNA. The amount of $P^{32}$-containing nucleotide removed on incubation accounted for 98 per cent of the nonlipid $P^{32}$ in the nucleus. When DNA and RNA were separated chemically from the isolated $P^{32}$-containing nuclei, it was found that the DNA contained no measurable radioactivity. The specific activity of the RNA was the same as that of the material released by incubation of an aliquot of the same nuclei at 37° C. and was higher than the specific activity of the RNA of the cytoplasmic particles by a factor of 13. It was concluded from the marked differences in specific activity that the RNA of the nucleus and that of the cytoplasm could not be the same substance.[18 to 21]

Experiments with regenerating liver showed that, during the first three hours after intravenous administration of $P^{32}$, the $P^{32}$ was held in the nuclear RNA in both the actively mitotic and the nonmitotic cells. It was known from previous experiments that after intervals longer than four hours, the $P^{32}$ was found in the DNA in tissues with rapidly dividing cells, but that in nongrowing tissue, the $P^{32}$ was removed from the nucleus to the cytoplasm. It was concluded, therefore, that in the nondividing cell the nuclear ribonucleoprotein could act as a precursor of cytoplasmic RNA, while in the dividing cell it might also function as the precursor of DNA. The four-hour interval mentioned above, which was required before $P^{32}$ could appear in DNA when taken together with the X-ray experiments on mitosis, indicated that DNA synthesis took place, not in the prophase, as had been supposed, but in the interphase. These experiments in demonstrating the release of polynucleotide gave experimental evidence for the first time of a mechanism whereby nuclear processes could control cytoplasmic activities.[18 to 21]

If the precursor theory were correct, then following $P^{32}$ administration the specific activity of the nuclear RNA of a nongrowing tissue should rise rapidly and then fall, and the specific activity of the cytoplasmic constituents, other than inorganic phosphate and phosphate esters, should at first be low and then rise as the nuclear specific activity falls. When the time sequence of specific activity changes was examined in rabbit liver, these expectations were fulfilled. The specific activity of the nuclear RNA reached a maximum three hours after injection of the $P^{32}$ and then fell off, while that of the large and small particles of the cytoplasm (mitochondria, microsomes) rose much more slowly and, eventually, reached the nuclear level within three days after injection.[22] This kind of experiment with normal livers was repeated with $C^{14}$-adenine and found[23] to give essentially the same results as with $P^{32}$.

In reporting the results of these experiments, it was pointed out that in analyzing turnover in a tracer experiment it was essential that a clear distinction be made between cellular turnover, *i.e.*, a condition in which the apparent turnover was due to formation of new cells and their disintegration, and a molecular turnover as in Schoenheimer's concept of a "dynamic equilibrium."[17,24] This distinction, until rather recently, has been ignored. Another biological factor generally overlooked was the possibility that different types of cells within the same organ might behave differently in turnover studies. It was shown that a short time after administration of $P^{32}$ the specific activity of hepatic cell nuclei was considerably higher than that of endothelial cell nuclei from the same organ, the liver.[25]

The previously mentioned experiments with isolated nuclei showed that polynucleotide was removed from the nuclei by action of some nuclear mechanism which was probably enzymatic in nature. If this process were also occurring *in vivo*, one should find in a tracer study that there was replacement, not just of nucleotides, but also of polynucleotides. One would then expect that, with $P^{32}$ as a tracer, the specific activities of the $P^{32}$ in the various nucleotides of the nuclear RNA would all be the same shortly after $P^{32}$ was administered and, furthermore, that while the specific activity decreased with time, all the values for the individual nucleotides should be in close agreement at any given time interval. Data were obtained for 3, 13, and 24 hours after the administration of $P^{32}$ to rabbits. The specific activities of the nucleotides at any one time were found to be the same within 5 per cent. The results were therefore consistent with the hypothesis.[26]

Since the turnover studies showed that the nuclear RNA behaved very differently from the cytoplasmic RNA, it was important that an effort be made to determine whether or not they were chemically different, particularly since the idea that there might be two or more kinds of RNA was at that time greeted with profound skepticism. The methods then available for nucleic acid digestion were not entirely adequate, and a

new procedure using strong perchloric acid was devised that gave quantitative yields of all the purines and pyrimidines, eliminating the necessity for correction for calculated losses and interconversions. With this method, it was also possible to make the base determinations without previously extracting the nucleic acids.[27] Applying this procedure, it was found that the ratios of the bases in the nuclear RNA of four different tissues of the same animal were, as a group, quite different from those of the cytoplasmic RNA of the same tissues. The group differences consisted of the existence of approximately one mol less of adenine, as compared to guanine, and relatively higher proportions of the pyrimidines in the cytoplasmic RNA. The nuclear and cytoplasmic RNA's were clearly different compounds, thus supporting the deductions reached in the turnover studies. Furthermore, these studies indicated that if the conversion of nuclear to cytoplasmic RNA did occur, a mol of adenylic acid would be released for every "tetranucleotide" converted, and thus suggested a possible source of the cytoplasmic adenine compounds. Moreover, in their pyrimidine ratios, no two of the RNA's, nuclear or cytoplasmic, could be considered the same. In fact, one was found to be completely lacking in uracil, while another showed only a trace of cytosine. These deviations and deficiencies were shown by control experiments not to be due to losses either in fractionation, digestion, or analysis. Thus the data suggested not only the release of adenylic acid, but possible transfer of other nucleotides as well. Since the RNA's of the nuclei of different tissues had very different pyrimidine ratios, and since these nuclei all arose from a single zygote nucleus, it followed that either the zygote nucleus contained a variety of RNA's or, if a single RNA was postulated, it would have to be assumed that with embryological development it was converted to a number of related but diverse types of RNA.[28]

From these experiments, it appeared that the metabolically active nucleic acid of the nucleus was the RNA, and that the DNA was, in this respect, inert. This was a strange property for a substance that was, and still is, considered by most investigators in this field to be the primary, or even the only significant constituent of the genes. Of course, it might be argued that a relatively inert, *i.e.*, a "stable" substance, was just what was needed for maintaining chromosomal or genetic continuity. If, however, the DNA were the primary genic material in the sense that it initiated gene reactions and that other possible gene constituents were directly or indirectly derived from it, then it followed that DNA should maintain its integrity in all cells capable of reproduction and in all stages of the division cycles. The reaction of nuclei of Arbacia eggs to cytological stains led us to doubt whether DNA was, in fact, present in these nuclei. They were not only negative to the Feulgen reaction, but centrifugation at high speed failed to produce aggregates of Feulgen-positive material as would be expected if the DNA was

present but merely dispersed.[29,30] Staining reactions alone, however, were not adequate proof of the absence of a compound, since it was always possible that some cellular constituent interfered with the reaction. Chemical information was therefore necessary but, because of the very small amount of DNA that might be present and the relatively huge amount of RNA known to be contained in the eggs, it seemed that, by the conventional methods, quantitative recovery of DNA or DNA bases could not be expected. The isotope dilution method was therefore used with $C^{14}$-thymine as the indicator that was added to the perchloric acid digest of lipid-free eggs. An appreciable amount of thymine was found, but cytological examination showed that the supposedly clean eggs contained considerable numbers of minute cells with strongly Feulgen-positive nuclei. When allowance was made for DNA of these cells whose number could not be counted accurately, since they occurred in spherical aggregates of 100 or more cells, and also for DNA of the polar bodies, the amount of thymine found that could be attributed to the egg cell itself was equivalent to five times the amount per sperm. If that much DNA were present in these nuclei, however, it could be shown that they should then give an easily detectible Feulgen reaction. The two types of observations appeared to be inconsistent only if the usual assumptions were made that thymine was contained only in the DNA, and that the DNA was contained only in the nucleus.[30] Possibly, then, there might be something wrong with these assumptions. It was obviously desirable to do a similar study on eggs either free of contaminants or in which the number of contaminating somatic cells could be accurately determined. Such a study was found possible with the sea urchin *Tripneustes*, in which the somatic cells were dispersed and could be accurately counted after suitable staining. Preparations of these eggs were extracted with cold dilute acid as well as with lipid solvents. Using the isotope dilution method, it was found that the amount of thymine present was just enough to account for the DNA of the contaminants and polar bodies, and left none that could be assigned to the eggs. This finding placed the assumptions mentioned definitely in suspicion and made it seem justifiable to conclude that there were no significant amounts of DNA in these eggs.[31] Since we had found previously that eggs in the earlier stages of maturation did contain DNA in amounts equivalent to six or more times that of the sperm, it was evident that the DNA must have been degraded in the stages of maturation at, or just prior to, polar body formation. Consequently, it would be expected that thymine-containing fragments of DNA would be found in the mature eggs. The acid-soluble fraction of *Arbacia* eggs was then examined for thymine. The amount found was 4.8 times the amount in the sperm, *i.e.*, just about the amount expected from the previous experiment in which the acid-soluble material had not been removed.[32,33] Evidently the DNA

was degraded at maturation and, taking together the results of all of the experiments with echinoderm eggs, it could be concluded that all of the egg DNA was so degraded. Since these eggs may be induced to develop parthenogenetically, *i.e.*, without the introduction of DNA from an external source, it followed that the DNA could not be the primary gene material but was a derived product. This conclusion is in direct contradiction to currently popular theories about gene structure.

Although the data lead to the exclusion of DNA as the initiator of gene reactions, it is clear from a number of experimental observations that DNA performs some important biological function. I shall mention only those observations having to do with the bacterial transforming substance that appears to be DNA, since these experiments, perhaps more than any others, have led to the implication that DNA is the sole or primary gene material.[34,35,36] What is clear from the data is that somehow the processes of synthesis are altered when the bacterial cell acquires the transforming DNA, so that a new phenotypic end product is formed and, too, that the capacity to produce this new product is retained with cell multiplication. More than that, one may consider that it is highly probable that the transforming DNA is incorporated into the bacterial nucleus. Experiments with $P^{32}$-labelled DNA injected into rats showed that it was incorporated into the nuclei of liver cells more rapidly than any of the other $P^{32}$-containing compounds tested, which led to the suggestion that this kind of process might be involved in bacterial transformation.[37] But these observations do not require that the DNA be either the sole genic material or the material responsible for the initiation of gene reactions, even though it may act upon or within the system we designate as the gene. As one component of that system, DNA action may not only be involved in the determination of phenotypic products but also, by intervention in the synthesis of new chromosomal material at the site where it is bound, create a new condition which is self-perpetuating.[31,38] This appears to be just the type of behavior shown by prophage.[39]

What, then, can be said about the function of DNA? Observations made with isolated nuclei, particularly the binding of desoxyribonuclease by nuclear RNA, suggested the hypothesis that DNA acted as an inhibitor of RNA, and the hypothesis was generalized to include inhibition of ribose derivatives by the corresponding desoxyribose compounds.[21,31,38,40] A wide variety of biological phenomena for which no other adequate explanation exists can be understood in terms of this hypothesis. Although they have been mentioned elsewhere, some of these phenomena will be listed here as an indication of the scope of the hypothesis: (1) differences in behavior of reciprocal crosses in plants and animals; (2) physiological and biochemical characteristics of interspecific Rana hybrids; (3) the short survival time of *Arbacia* eggs as compared with the longevity of their parthenogenetic merogones; (4) the system of

Ds-Ac modifiers in Zea; (5) enzyme activity in biochemically deficient mutants of *Neurospora;* and (6) the behavior of phage and prophage after infecting the host cell.

Looking back over both series of experiments that I have outlined, we find similar, and possibly related indications, arising from both of them. The different response patterns to radiation of interphase chromosomes of different tissues in the same animal indicated structural differences in these chromosomes. The analyses of the nucleic acids showed that there were differences in the composition of the nuclear RNA but not in the DNA of different tissues of the same animal. In both cases, it was necessary to postulate either that a diversity of chromosomal structural conditions and of ribonucleic acids was present in the zygote nucleus and that these were not uniformly distributed during embryological development, or that only a single structural state and a single ribonucleic acid were originally present and that these became altered with differentiation to produce the multiplicity observed. At present, there are no experimental data that would enable us to choose between these alternatives. It is clearly possible, however, that a rather large number of different ribonucleic acids are contained in the zygote nucleus. Differences in the distribution of these ribonucleic acids to the various loci of a chromosome would provide for genetic specificity, although these acids are not necessarily the only specificity-determining elements of the locus. Furthermore, extrapolating from the experiments with isolated nuclei, differences between alleles may be accounted for by differences in rates of release of polynucleotide at any one locus.[21,38] If there is any function that all genes and all chromosomes have in common, it is that of self-reproduction, and we found in the results of the radiation experiments that there were clear indications of histones taking part in this process. There are, then, at least three components involved in chromosome function with the ribonucleic acids, probably in combination with the histones functioning as a kind of driving mechanism and with the desoxyribonucleic acids behaving as a sort of governor. But can we assume, as we might be inclined to do from genetic data only, that these, and possibly other as yet unknown components, are limited in their interactions to the confines of the regions designated as the genetic loci? The radiation experiments argue against such a conclusion. It was found that although breaks could be produced anywhere along the chromosome, inhibition of mitosis resulted from action on very limited chromosome sections probably identical with the centromeres. Since, at the stage of inhibition, the chromosome is hundreds of microns long, energy absorbed in one short section could not affect remote regions of the chromosome unless there existed some mechanism whereby the activity at all loci was integrated with the function of these sections, for such activity is required in

the developments that eventually lead to the separation of chromonemata at the onset of the prophase. The whole chromosome, therefore, or possibly the whole chromosome complex must be composed of spatially separated but functionally interrelated components, and genes are not independent, but conveniently recognizable units in this system. The more recent genetic data support this deduction, for even the traditional criterion of noncrossing over within the gene no longer applies, and it has become customary, where such crossing over has been found, to resort to the device of calling the units at these loci, compound genes.

There does not emerge from these experiments a comfortingly simple model of the gene such as a template of DNA. In our preoccupation with the search for a template, we have overlooked the possibility that the regularity with which a locus or gene reproduces itself is not necessarily determined by the exact reproduction of a single governing molecular species. Stable but nonstatic conditions may result from the interaction of components of a system containing a large number of units of a few or many species. We have examples at the molecular level in chemical reactions under equilibrium conditions and at higher levels of organization in the relative constancy of the composition of populations of living organisms under given ecological conditions. Neither the simple template nor the mixed-population concepts will fit all of the experimental results I have mentioned. It is possible to conceive of a model that would fit the requirements of at least two or three spatially fixed components with specificity-conferring characteristics and at least one communicating, probably mobile, component. Any such model can be only suggestive at this time. The need is for more experimental information.

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## *SECTION OF BIOLOGY**

# "CASTRATION CELLS" IN THE CENTRAL NERVOUS SYSTEM OF AN INSECT (*LEUCOPHAEA MADERAE* BLATTARIA)**

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Investigations in recent years have led to the identification of groups of neurosecretory cells in the central nervous system of vertebrates and invertebrates as sources of specific endocrine substances (for a recent review, see Scharrer and Scharrer 1954b). In insects, for example, such cells in the protocerebrum have been shown to produce hormones controlling reproduction and postembryonic development. It is reasonable to assume, therefore, that other neurosecretory cells whose function is still unknown are also endocrine elements. In a search for their physiological significance, a classical method, much used in vertebrate endocrinology, may also be applied to invertebrates such as insects. This method is based on the observation of cytological changes in organs of internal secretion as a reflection of different physiological states or disturbances of the normal endocrine pattern. This approach was used in a study of the microscopic appearance of certain neurosecretory cells in the subesophageal ganglion of the insect *Leucophaea maderae*, which includes dated normal animals and specimens which have undergone a variety of operations such as castration and allatectomy.

### *Material and Methods*

The material on which the present report is based consists of dated normal specimens of various ages, as well as allatectomized and castrated males and females. In addition, a small number of animals whose recurrent nerve had been severed were included. With the exception of two last instar normal female nymphs, all specimens were adults. Serial sections of five micra thickness through the subesophageal ganglia were stained with the aldehyde fuchsin technique of Gomori (1950), as modified by Halmi (1952) and Dawson (1953). The majority of the specimens had been fixed in Helly's solution, which proved superior to Bouin's for the purposes of this study.

Fifteen normal female imagos ranging from 213 to 490 days of adult age (period between emergence and fixation) were selected so as to

*Two papers were presented in a symposium of Endocrine Mechanisms in Insects at a meeting of the Section on April 11, 1955. The first paper in this symposium was entitled "The Function of the Prothoracic Glands in Insects" by Dietrich Bodenstein. No abstract of this paper has been received.

**This paper, illustrated with lantern slides, was the second of two papers in the symposium on Endocrine Mechanisms in Insects presented at the meeting of the Section on April 11, 1955.

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represent various stages of the reproductive cycle. Eight normal males had an adult age of from 209 to 480 days. All castrates studied had been gonadectomized in nymphal stages. Among 14 females in this group, the period of castration before emergence into the adult stage varied between 44 and 137 days. Their adult age at the time of fixation was 142 to 273 days. The total period over which the animals had been allowed to survive as castrates was a minimum of 225 days and a maximum of 358 days. The corresponding intervals for the 13 castrated males were 33 to 104 days between castration and emergence, and 138 to 303 days between emergence and fixation. The total interval between castration and fixation in this group varied from 189 to 358 days. Allatectomy was performed in young adults. Eighteen females were fixed 182 to 364 days after the operation; in 10 males this interval ranged from 204 to 344 days. In addition, three adult females whose recurrent nerve had been severed for 269 to 282 days were examined.

### *Observations*

As has been previously described (Scharrer 1941), the subesophageal ganglion of *Leucophaea maderae* contains neurosecretory cells. With the aldehyde fuchsin method used in the present study, the various types of secreting nerve cells in the central nervous system can be demonstrated more readily than with the procedures employed in earlier work. A detailed description of these cells in *Leucophaea* will be given in a separate publication. For the present, it is sufficient to state that most conspicuous among the neurons of the subesophageal ganglion are large elements whose cytoplasm contains granules that stain deep purple with the aldehyde fuchsin technique (A cells). The granules appear red in sections stained with the Masson-Foot method, and deep blue with Gomori's chrome hematoxylin phloxin. In all of the adult specimens studied, both normal and operated, these cells and part of their axons are packed with these conspicuous inclusions, whereas the corresponding cells in the nymphs show much less stainable material.

Each subesophageal ganglion contains four of these neurosecretory A cells. Whereas their number seems to be constant, there is a certain variability in their location. Typically, these cells form a lateral and a ventrolateral pair (FIGURES 1, 2) which serve as convenient landmarks.

In the vicinity of the ventrolateral A cells, *i.e.*, more medial and slightly more caudal from them, another pair of large cells (B cells) can be distinguished. These cells are characterized by a delicate layer of marginal granules that also stain purple with aldehyde fuchsin (FIGURE 1) in all types of animals studied, with the exception of the gonadectomized females. In these animals, a cytologically different cell type ("castration cells") takes the place of the B cells. The cytoplasm of

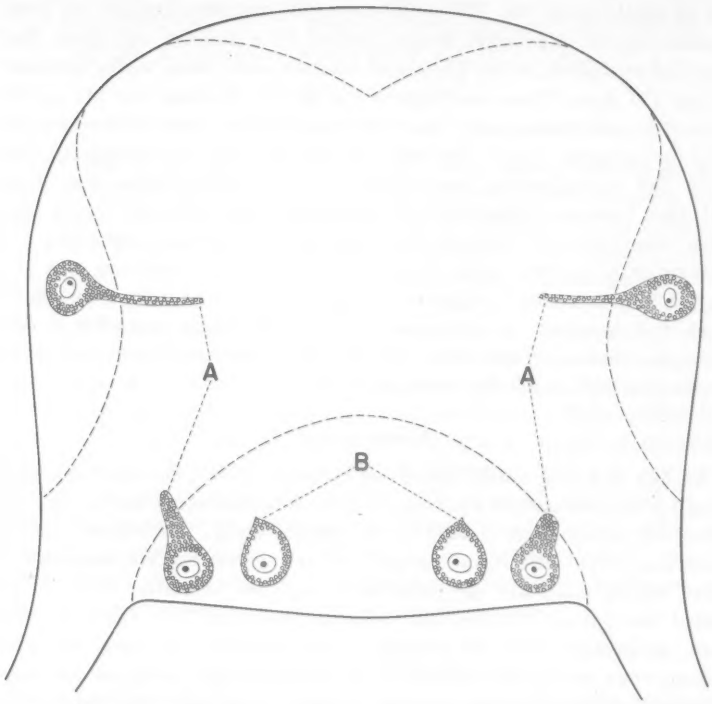


FIGURE 1. Diagram of subesophageal ganglion of *Leucophaea maderae*, typical of normal adult, showing two types of neurosecretory cells. The A cells are filled with granules (indicated by clear circles) staining deep purple with the aldehyde fuchsin technique. The B cells contain fewer purple granules in the cell periphery.

the castration cells usually contains a larger amount of granular inclusions located predominantly in the cell periphery and near the axon hillock. Instead of purple, these granules stain a conspicuous green in sections treated with Halmi's method (FIGURE 2). This distinctive staining property allows the pair of cells to be readily identified at low magnification. It was found in all of the 14 female castrate specimens examined.

In addition to these cases, two earlier cases from an experimental series of female castrates prepared for a different purpose were available for comparison. In these specimens, stained with Foot's modification of the Masson stain, the castration cells also contain green granules. Thus, the cytoplasmic inclusions typical of the castration cells of

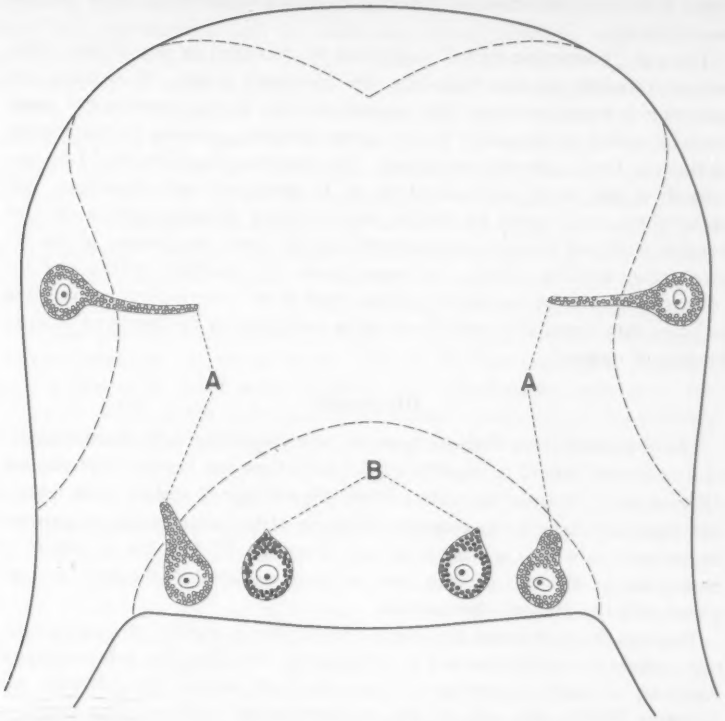


FIGURE 2. Diagram of subesophageal ganglion of adult gonadectomized female *Leucophaea*. A cells unchanged. Instead of normal B cells, note pair of "castration cells", containing inclusions (indicated by black dots) staining conspicuously green with the aldehyde fuchsin technique.

*Leucophaea* appear to have an affinity for the light green component of a given mixture of dyes, irrespective of the type of procedure followed. This staining property needs further study.

Besides the two B cells in the vicinity of the ventrolateral A cells, the medial posterior area of the ganglion may contain several cells of the same type, *i.e.*, elements with few purple inclusions. These granules, if present at all, are less conspicuous and less regularly arranged than in the pair of B cells shown in FIGURE 1. Correspondingly, in certain of the female castrates studied, the equivalent cells of the medial posterior zone contain green-staining inclusions. Furthermore, there are occasional green-staining small bodies which seem distributed more or less at random in or near the cells of the subesophageal ganglion. Such inclusions, however, are not restricted to castrated females, but also

occur in noncastrate animals. The origin and significance of these bodies are unknown.

Typical "castration cells" could not be detected in any of the other animals studied so far, including the castrated males. This does not necessarily mean, however, that normal animals do not produce the same material which is signalled by the green-staining granules in the female castrates. Under normal conditions, this substance either could be released at the same rate at which it is produced and, therefore, not accumulate, or it could be visible as a cellular storage product only at certain brief and as yet undetermined periods, such as phases of the reproductive activity. Since, in *Leucophaea*, the ovarian cycles and related changes in the metabolic pattern may show a considerable variation in time, this possibility will have to be explored on the basis of a large number of cases.

## *Discussion*

The discovery of a distinct type of neurosecretory cell characteristic of a castrated animal is significant for more than one reason. Cytological differences in correlation with certain physiological states, both normal and abnormal, have been observed for some of the neurosecretory centers in various animals (see Scharrer and Scharrer 1954a), but no effect of castration on the cell picture has yet been reported that could be compared with the present observation.

Whereas the endocrine function is known for a variety of neurosecretory centers in vertebrates and invertebrates, including the subesophageal ganglion of certain species of insects (see review by Scharrer and Scharrer 1954b), the role of the neurosecretory cells of this ganglion in *Leucophaea* has remained undetermined thus far. The marked cytological change in the secretory behavior of one cell type after castration, as described in this paper, opens new possibilities for the study of their physiological significance.

Furthermore, the question as to whether insect gonads produce sex hormones is still uncertain (see B. Scharrer 1953). The effect of ovariectomy on the cytology of a neurosecretory cell type, as described here in *Leucophaea*, offers indirect evidence that, at least in the female, the gonad may function as an endocrine organ. The fact that a corresponding effect was not observed in the male does not seem too surprising since, among insects, endocrine relationships in reproduction assume greater significance in the female of the species than in the male.

The observation that the secretory product of the "castration cell" takes up a different component of the mixture of dyes used than do the inclusions of most other types of neurosecretory cells is not unique. It would seem that such differences in stainability reflect differences in the cellular products that can be interpreted as indicating the presence either of more than one hormone type, or of different types of carrier sub-

stances with which these hormones are associated. The castration cell may well represent a cell in which an active principle, signalled by green-staining inclusions, has accumulated while it is either absent, or present only in small amounts, in the male and the noncastrate female.

The term "castration cell" is suggested only tentatively for the neurosecretory cell type which stains green in the female castrate of *Leucophaea*. Although not analogous in every respect to the "castration or sterility cell" of the anterior pituitary of vertebrates (Romeis 1940), it is, nevertheless, comparable to it. In both cases, we are dealing with a cytologically distinct cell type of endocrine nature that is characteristic of the castrated animal. Therefore, it suggests certain functional relationships between the gonad and the organ in which this cell appears. From the present observation, it would seem that, in the insect *Leucophaea maderae*, secreting nerve cells in the subesophageal ganglion play a role in at least some phase of the reproductive activity of the female for which other endocrine relationships, especially a dependency on the corpus allatum, have been demonstrated before (Scharrer 1946).

## *Summary*

In gonadectomized females of the insect *Leucophaea maderae*, the subesophageal ganglion contains a pair of cytologically distinct neurosecretory cells whose cytoplasmic inclusions stain a pronounced green with the aldehyde fuchsin technique, whereas other neurosecretory cell types take up other components of the same mixture of dyes. These green staining "castration cells" are absent in all other specimens examined, including castrated males, normal and allatectomized adults of both sexes, and animals with severance of the recurrent nerve. This observation suggests an endocrine relationship between neurosecretory cells in the subesophageal ganglion and the female gonad.

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## *SECTION OF BIOLOGY*

# THE PROPERDIN SYSTEM*

*By* Louis Pillemer

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Properdin, complement, and $Mg^{++}$ are the recognized constituents of the properdin system, a natural defense mechanism of blood. [1] This system kills certain bacteria, neutralizes some viruses, and lyses certain abnormal erythrocytes in the absence of specific antibodies. Alterations in the serum properdin levels *in vivo* [2] appear to influence the course of certain experimental infections [3] and the susceptibility of laboratory animals to the effects of total body irradiation. [1, 4]

Pillemer opened the symposium by summarizing the events [1] leading to the discovery of properdin, its isolation from serum, and the requirements for complement and $Mg^{++}$ as essential co-factors. Initially, properdin was demonstrated as a factor necessary for the inactivation of the third component of complement (C′3) by zymosan** at 37°C. This inactivation does not occur at 15°C. However, zymosan forms an insoluble complex (PZ) with properdin at 15°C. leaving the serum deficient in properdin (RP). The addition of zymosan to RP does not inactivate C′3 but, upon the addition of purified properdin, full inactivation of C′3 occurs. Thus, properdin is essential for the interactions of complement with zymosan. Properdin-deficient serum (RP) contains the components of complement, hemolytic activity against sensitized cells, natural antibodies, clotting factors, and the plasmin system.

**Zymosan [5] is the purified cell-wall residues of fresh yeast. The cell walls of many bacteria possess this property. Recently, we have shown that certain *native* dextrans and levans, as well as other carbohydrate complexes, are also able to combine with properdin and to inactivate C′3.

The reaction of properdin with zymosan requires complement, $Mg^{++}$, an ionic strength less than 0.4 and temperatures greater than 10°C. None of these conditions is required for the combination of antigen with antibody. The properdin-zymosan (PZ) complex also differs from antigen-antibody complexes in its effect on hemolytic complement. The PZ inactivates C′3 with little effect on the other components of complement, while typical antigen-antibody complexes destroy the other components and have little effect on C′3.

Properdin elutes from PZ in solutions of high ionic strength at slightly alkaline pH, and this is the basis for its purification. After subsequent dialysis and ultracentrifugation, it has been purified 7000-fold with a yield of approximately 50 per cent. Properdin represents about one to two micrograms of protein nitrogen per milliliter of normal human serum.

*This paper is a summary of a symposium on The Properdin System presented, illustrated with lantern slides, at the meeting of the Section on March 14, 1955. The participants were William S. Jordan, Jr., Thomas Hale Ham, Carl F. Hinz, Jr., Alan R. Moritz, Louis Pillemer, Oscar A. Ross, Derrick Rowley, and Alastair C. Wardlaw.

In the purified state, properdin behaves as a euglobulin with minimum solubility between pH 4.8 to 6.5, and has a sedimentation constant of about 27S. It is stable to heating at 66°C. for 30 minutes, but is destroyed at 100°C. for five minutes.

The measurement of properdin depends upon its ability, when added to a properdin deficient (RP) serum, to inactivate C'3 in the presence of zymosan. In the actual assay, varving amounts of test serum or sample are added to constant amounts of RP and incubated at 37°C. for one hour with a standard amount of zymosan. The fall in C'3 titer in the test mixture is a measure of the amount of properdin present in the sample. A unit of properdin is that amount which will reduce the C'3 titer of RP from 120 to 0 units on incubation with zymosan under standard conditions. While there are theoretical and practical objections to the zymosan assay, it is reproducible and not difficult to perform. [1] However, careful selection of reagents such as RP and R3 is necessary. About 20 per cent of human serums make suitable RP, and only about 10 per cent make suitable R3.

It was pointed out that, in order to determine the full importance of properdin in natural immune mechanisms and related phenomena, further work was necessary on (1) the mechanism of action of the properdin system; (2) the improvement in the methods for the assay of properdin; (3) the characterization of properdin; and (4) the identification and isolation of the substrates with which it interacts.

Hinz discussed the role of the properdin system in hemolytic reactions. [1, 6] The properdin system is necessary for the hemolysis *in vitro* of certain abnormal human erythrocytes, including those from patients with paroxysmal nocturnal hemoglobinuria (PNH) and also normal erythrocytes which have been treated with weak solutions of tannic acid (TA cells). Both of these reactions involve destruction of defective human cells by normal serum constituents and no antibody is involved. None of the antibody requiring hemolytic reactions that have been tested require the properdin system.

PNH is a rare acquired hemolytic anemia, in which the patient's cells are hemolyzed by his own or normal human serum. The reaction requires a temperature greater than 25°C., and has an optimum pH of 6.8, the same pH optimum for the combination of zymosan with properdin.

The following observations show that the properdin system is required for PNH hemolysis: (1) serum, deficient in properdin but not in complement (RP), fails to hemolyze PNH erythrocytes; (2) purified properdin from human, cow, or hog serum, specifically restores the hemolytic property of RP, but is not hemolytic by itself; (3) serums from which any component of complement, or from which $Mg^{++}$ have been removed, fail to hemolyze PNH cells, and these serums do not become hemolytic on adding properdin; and (4) the properdin titer of untreated serum corresponds to the hemolytic activity of that serum.

PNH erythrocytes are impractical for investigations of the properdin system, but cells with similar characteristics and requirements for hemolysis are desirable. Normal human erythrocytes treated with weak solutions of tannic acid (TA cells) are hemolyzed similarly to PNH cells by the properdin system. TA cells are hemolyzed by normal serum at 37°C. in the presence of properdin, the components of complement, and $Mg^{++}$. RP fails to lyse such cells, but the addition of purified properdin to such serum restores its hemolytic properties. The amount of hemolysis is directly proportional to the amount of properdin added to such serum. This last observation suggests that TA cells may be useful for the measurement of properdin levels in human and animal serum.

Wardlaw, in the next presentation, showed that the properdin system of human serum participates in certain bactericidal processes. [1, 7] This was first shown with a strain of *Sh. dysenteriae*, which is rapidly killed when exposed to serum at 37°C., but not when exposed to a properdin-deficient serum (RP). A mixture of RP and purified properdin, however, is highly bactericidal, although properdin by itself is completely inactive. Thus, the bactericidal action of normal human serum against *Sh. dysenteriae* appears to depend on the joint action of properdin and other serum factors. The latter resemble complement in their thermolability and in their sensitivity to various treatments known to inactivate complement. The RP used in bactericidial tests differs from the reagent employed for the zymosan assay of properdin. It is prepared by a two-step treatment of serum with zymosan, first for 75 minutes at 17°C., then again with fresh zymosan for 30 minutes at 37°C. After each treatment, the zymosan is removed by centrifugation. About 50 per cent of human serums can be converted by this method into RP that is satisfactory for bactericidal tests, *i.e.*, RP, which by itself causes no loss of viability of *Sh. dysenteriae* during 90 minutes at 37°C. but which, in the presence of added properdin, kills 90 to 100 per cent of the organisms.

A graded bactericidal response is obtained with different concentrations of properdin and constant amounts of RP. This is the basis of a bactericidal method of assaying properdin. The properdin content of serum titrated by this method is similar to that obtained in the zymosan assay, in the case of human, rabbit, and guinea pig serum, but with rat, mouse, and dog serums, the bactericidal method gives properdin titers much lower than those obtained in the zymosan assay. It has also been found that specific antibodies may interfere with the bactericidal assay of properdin. The bactericidal action of the properdin system involves lysis of the organisms and resembles an enzymatic reaction in its temperature dependence and in that properdin itself does not appear to be used up. In addition to *Shigella dysenteriae*, strains of *Salmonella*, *Pseudomonas*, *Proteus*, *Paracolobactrum*, *Escherichia*, and *Bacillus* are sensitive to the properdin system. This sensivity is a consistent property of each strain,

but not of different strains within a species, or of different species within a genus. In several genera, in addition to the presence of properdin-sensitive strains, there are strains that are highly sensitive both to serum and RP, and also strains insensitive to the bactericidal action of human serum.

Ross summarized studies on the properdin system in radiation illness and experimental infections. [1, 4] Following lethal doses of total body irradiation in rats and mice, the serum properdin falls rapidly to under 30 per cent of normal levels. The intravenous injection of purified bovine and human properdin into irradiated rats and mice significantly protects them against LD 100/30 day and LD 100/6 day doses. The degree of protection depends on the dose, route, and time of administration of properdin. Properdin-treated mice, which were protected against 820 r. whole body irradiation (65 per cent of animals protected by intravenous injection of 50 units of bovine properdin 2, 24 and 48 hours after irradiation), gained weight and have remained healthy to date (6 months after irradiation). These animals also fail to show any of the recognized gross stigmata of total body irradiation.

Experimental infections in mice with *Escherichia coli* and *Klebsiella pneumoniae* also show a relationship between properdin levels and the survival of infected animals. The course of infection in these animals is markedly altered by the intravenous administration of properdin.

The parenteral injection of zymosan, which combines with properdin *in vitro*, causes marked alterations in serum properdin levels of laboratory animals. [2] Within one hour after the injection of zymosan, serum properdin titers fall to under 20 per cent of normal levels, followed, after 2 to 10 days, by marked rises in titer 200 to 300 per cent above normal levels. Parenteral administration of zymosan, either 24 hours before or after irradiation, has resulted in 70 per cent protection of mice against an LD 100/30 day doses. These observations indicate that the rise in blood properdin that follows the injection of zymosan influences the resistance of animals to the bacteremia that follows lethal doses of total body irradiation. Proper administration of zymosan prior to infection also significantly protects mice against *K. pneumoniae*.

Derrick Rowley [3] summarized his experiments on *E. coli* infections in mice. Small amounts of purified cell walls of a virulent strain of *E. coli* and large amounts of cell walls from an avirulent strain inactivate CA3 and combine with properdin. The avirulent strain is more susceptible than the virulent strain to the properdin system. *E. coli* cell walls resemble zymosan in their ability to interact with the properdin system.

The injection of *E. coli* cell walls or zymosan into mice causes marked changes in their susceptibility to experimental *E. coli* infections. During the first hour after the injection of cell walls, when the properdin titer is low, the mice become very susceptible to infection with an *E.*

*coli* strain which was avirulent for normal mice. Moreover, during the period between two and five days after injection of zymosan, when the properdin titers are elevated, the mice are highly resistant to a virulent strain of *E. coli*. In addition, rats that are naturally resistant to *E. coli* infection are killed by this organism if zymosan has been injected one hour preceding challenge. These results suggest that the initial fall and secondary rise in blood properdin that follows parenteral administration of zymosan or *E. coli* walls may influence the natural resistance of animals to *C. coli* infections.

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## *SECTION OF MATHEMATICS AND ENGINEERING*

# AN ELECTRODYNAMIC EFFECT IN ELECTROSTATICS*

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We have observed an electrodynamic effect which is quite significant from the scientific standpoint, one which, to our knowledge, has never been reported before.

When two fine wires, A and B for example, are charged from any electrostatic source whatever, the A wire positively and the B wire negatively, it will be noted that, when a certain electrostatic potential V has been reached, the two wires will rotate evenly. The amplitude of rotation $\Omega$ and the frequency of rotation $f$ depend essentially on the intensity of the electric field (E) arising between the two wires. No set arrangement of the wires relative to each other is required. They may lie in a horizontal, vertical, or oblique plane, and may be parallel, oblique, or even perpendicular to each other. The wires will emit a characteristic glow. Depending on the potential V, and whether it be positive or negative, the rotating wires are seen to describe, especially in darkness, pisciform or looplike figures of a bluish to bluish-violet hue in the case of wire A, while, in the case of wire B, figures of similar shape appear but seem to be comprised of a series of fine luminous circles. In addition to occurring in regular air, the phenomenon will occur in any number of gases, among them, $O_2$, $H_2$, $N_2$, CO, and $CO_2$. This phenomenon has also been observed in atmospheric air that is either rarefied or compressed. Only when the critical value $E_c$ of the electric field E has been reached does the phenomenon occur. This critical value $E_c$, which is subject to variation, is a function of the constant dielectric of the fluid medium used.

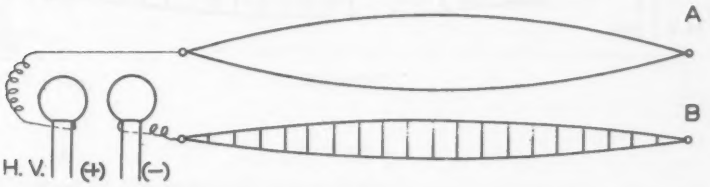


FIGURE 1

FIGURE 1 gives one illustration of the phenomenon. In this instance we have two wires of electrolytic copper, 0.2 mm. in diameter, suspended parallel to each other on insulated supports in regular air at atmospheric pressure ($p$ = 760 mm. Hg), at a temperature of 20° C. No discernible increase in temperature occurs in the wires as a result of corona effect.

*This paper, illustrated with lantern slides, was the first of two papers presented before the Section on April 15, 1955.

The wires are both 80 cm. long and are 7.5 cm. apart. They commence to rotate when the difference of potential V = 28 kV, starting with a very small amplitude $\Omega$, roughly 1 mm. in diameter, and at a very low frequency $f$ (approximately one revolution per second). The amplitude $\Omega$ then increases progressively until it reaches nearly 6 cm., and the frequency $f$ increases to about 25 r.p.s. A certain period of time is required for the rotatory motion to become fully established, in this present experiment 4.5 seconds, after which it continues evenly. The amplitudes $\Omega$ and frequencies $f$ of rotation of the two wires are usually quite different. In general, the positively charged wires are the first to start rotating, and they proceed to develop greater amplitudes and frequencies than the negatively charged wires $\Omega_A > \Omega_B$ and $f_A > f_B$. For a very large range of differences in potential $V_A - V_B$ the negatively charged wires have extremely small amplitudes of rotation, which are barely perceptible, or they may not rotate at all. When at rest, they emit a corona effect characteristic of negative charges, consisting of luminous points.

The phenomenon will occur also when one of the wires is grounded. Let us suppose that wire B is grounded. Wire A, connected to a positive pole (+), starts to rotate and activates wire B (FIGURE 2). Should wire A, on the other hand, be connected to a negative pole (-), then only wire B will rotate (FIGURE 3). As in the previous instance, the amplitude $\Omega$ and the frequency $f$ are functions of the electric field E. Instead of having only the two wires A and B, we may have a system of several wires, $A_1$, $A_2$, $A_3$, and $B_1$, $B_2$, $B_3$. All the positively charged wires will then be rotating with different amplitudes, $\Omega_1$, $\Omega_2$, $\Omega_3$ and different frequencies,

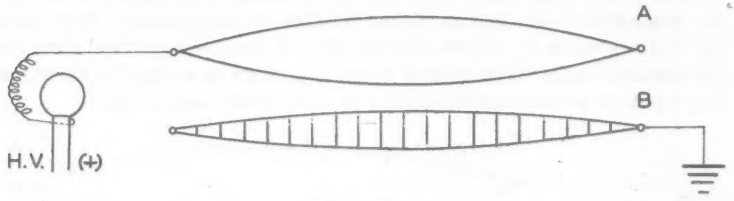


FIGURE 2

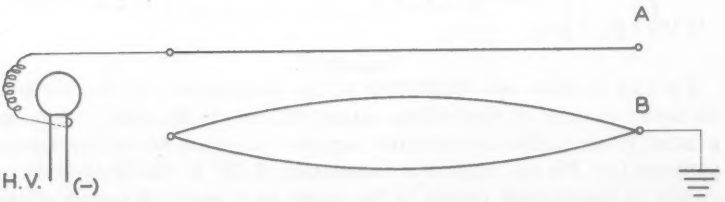


FIGURE 3

$f_1$, $f_2$, $f_3$. The same would be true in the case of the grounded wires. which undergo excitation from one or more negatively charged conductors. We have established that the wires may be made of practically any metal or alloy.

The question arises as to the basic mechanics of this phenomenon. Why does it occur? To begin with, we may assume that the electrons emitted by the negative wire (-) strike the positive wire (+), and produce there an electrodynamic couple of rotation C, whereupon they then flow evenly, either toward the electrostatic source or into the ground. Their flow constitutes a veritable electric current *i*, necessarily accompanied, under the well-known general law, by a whirling magnetic field H. In their avalanchelike movement from B to A, as they pass, either through the air or through some other fluid medium, the electrons are subjected, on the one hand, to the propulsive force $F_E$, which stems from the electric field E and, on the other hand, to the deflective force $F_H$, which stems from the magnetic field H. In the present case, the force $F_E$, deriving from the electric field E, will always be the greater, since the very existence of the current *i*—hence of the magnetic field H—results from the electrons' striking the positive wire (+). Whether the wire rotates to the right or to the left depends on the direction of the resultant F of the forces $F_E$ and $F_H$, which is applied to the wire the instant rotation begins. In other words, the direction of rotation depends on the conventional sign for the direction of the vector force F, equal to the geometric sum of $F_E$ and $F_H$.

One of the wires, more often the one that is positively charged, may rotate in fractional harmonics. FIGURE 4 shows rotation in two harmonics. This division into harmonics is explained by the fact that differing resultants of the forces F (+ and -) are exerted on the wire and produce there couples of forces having opposite directions.

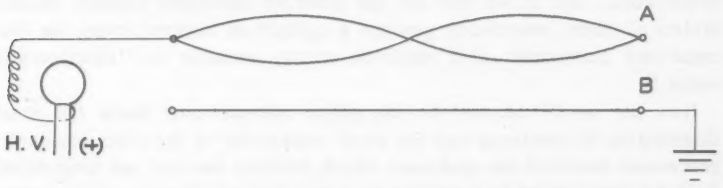


FIGURE 4

Rotation ot the negatively charged wire can be explained by the fact that some of the electrons, emitted originally from the negative wire, do not reach the positively charged wire. Instead, they fall back upon the negative wire, producing there electrostatic couples of forces.

The phenomenon will likewise occur when one wire is connected to one of the poles of an electrostatic source, and the other wire is left open (FIGURE 5). Generally speaking, the rotation will occur sooner if the open wire is first grounded, then disconnected afterward. One curious

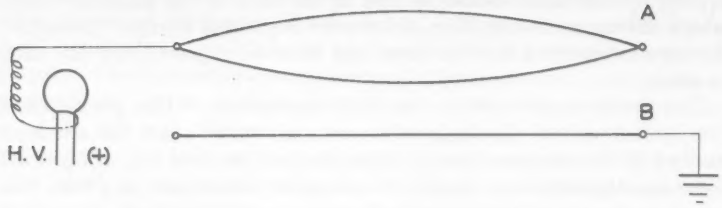


FIGURE 5

aspect of the case just mentioned is that the wire may be made to rotate by holding near to it a piece of flint or a lighted cigarette, but the flame of a lighted candle held in the same proximity will have no effect at all. The reason for this is that burned gases generally contain a certain quantity of electric charges of like sign, and these will commence to move if placed in the vicinity of any electric potential. The electrons resulting from this will strike against the wire and produce the rotations. It is the other wire, the one in open circuit, which helps to keep the rotation going by taking in from the atmosphere the electrons which it subsequently ejects toward the rotating wire. A pure flame, on the other hand, causes ionization of the atmosphere, *i.e.*, it produced electrical charges of opposite sign. The flame is seen to flicker, as might be expected, by being first attracted, then repulsed, but the absence of free electrons makes impossible the rotation of the wire. Ionization in no way helps to produce or maintain the phenomenon in question.

If, instead of a single wire, preferably a negative wire (-), we use a whole system of wires, or an electrode of any kind, a hollow metal cylinder for example, the walls of which are either solid, grated or of screenwork, and if we use as our positive electrode another similar system of wires, resembling perhaps a cylindrical squirrel cage, we find ourselves possessed of a veritable motor, actually an "electrostatic motor."

How are we to account for the above phenomenon? Since the exact distribution of electrons and the great complexity of the electromagnetic processes involved are problems which science has not yet unravelled, it is not easy for us to formulate here any definite conclusion. Nevertheless, the phenomenon is revealing. It obliges us to concede, for the moment at least, that we are faced with what seems to be an instance of electrodynamic forces, *i.e.*, forces of electromagnetic origin acting on a purely electrostatic system. This would seem to support our theory, put forward on several occasions over the past few years, to the effect that an electrostatic field should not be regarded as an entity in itself, but only as one aspect of the basic phenomenon of electromagnetism.

In relation to this theory, we have conducted the following experiments: We again connected the wire A to the positive pole of an electrostatic

source and, as before, we sent through the wire B a direct current $i$, which emanated from a separate low-voltage source. We observed that the wire A rotated as before, emitting the white glow characteristic of positive charges (+). Although wire B also rotated, the glow it emitted had quite a different appearance, resembling a series of bright, necklace-like circles of light, all lying in parallel planes, the center point of each being on the longitudinal axis of the dull, bluish, looplike figure described by the rotating wire (FIGURE 6). Generally, the amplitudes of rotation $\Omega$ and the frequencies of rotation $f$ of the wire A exceeded those of the wire B ($\Omega_A < \Omega_B$ and $f_A < f_B$). When wire A was connected to the negative pole (-), however, wire B still being traversed by the direct current $i$, then only wire B rotated (FIGURE 7), emitting the constant glow characteristic of positive charges (+). Finally, the same result was obtained with alternating current, with 110 volts and 60 cycles, for example. In this case, when wire A was connected to the positive pole (+), wire B rotated and emitted the necklacelike circles of light mentioned above, which were clearly visible to the naked eye. Wire A also rotated but with an amplitude $\Omega$ and frequency $f$ much inferior to B. Again, the glow emitted by A was characteristic of positive charges (+). Likewise, when wire A was connected to the negative pole (-), it did not rotate, and it was then wire B that rotated and emitted the positive glow.

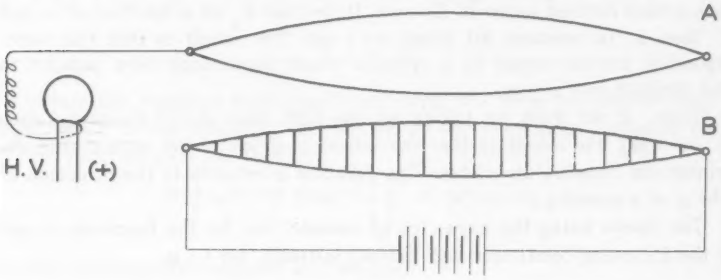


FIGURE 6

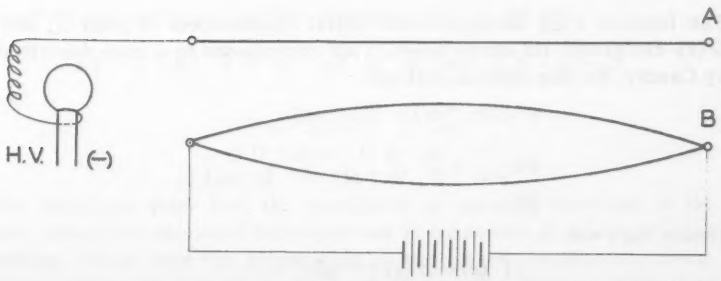


FIGURE 7

In the preceding experiments, a magnetic field H was engendered around the B wire before the electric field E could begin to act. The result was a certain interaction between the magnetic field H and the electric field E. It is our view that it is this interaction that is responsible for the above-described phenomenon, which at first glance might appear to be exclusively electrostatic in nature.

### *Mathematical Analysis*

Let us assume, first of all, that the vibratory rotations of the wire and the whirling of the fluid medium are without spatial limitation. This being the case, we may start with the well-known formula of mathematical physics $\rho\frac{\partial^2 u}{\partial t^2} = \tau\frac{\partial^2 u}{\partial x^2}$ in which the factor of gravity as it relates to the tension of the wire is disregarded, the tension of the wire being considered constant. In this formula, derived from Euler's wave equation, $\rho$ represents the density of the wire and $\tau$ the coefficient of the elastic tension of the fluid medium. If, in the interest of simplicity, we state that $a^2 = \frac{\tau}{\rho} = C^{te}$ and if we then perform the operation after the method of Dalembert, we get $u = \phi(x + at) + \psi(x - at)$, where $\phi$ and $\psi$ are arbitrary functions, doubly differentiable.

The two parts of this solution have an obvious and simple expression. Let us say that $u_1 = \psi(\eta) = \psi(x - at)$. For each value of $\eta$ the function $u_1$ has a well-defined value of its own. If we take $u_1$ as a function of $x$ and $t$, then $u_1$ is constant all along $\eta = x - at$. The result is that the corresponding surface would be a cylinder whose directrices were parallel to the straight line $x = at$.

Thus, if we start by taking as the first term of the above solution $\phi\ (x + at)$, the result is that the initial position of the wire during the vibrations remains invariable. The function $u$ extends in the direction of the $x$ at a speed $a$.

The above being the case, let us assume that for the functions $\phi$ and $\psi$ the following conditions will prevail initially, for $t = o$,

$$u = F(x) \text{ and } \frac{\partial u}{\partial t} = G(x)$$

The function $F(x)$ designates the initial displacement of point $x$, and $G(x)$ designates its initial speed. This corresponds to a case described by Cauchy. We may write as follows:

$$u = \phi(x + at) + \psi(x - at),$$

$$\frac{\delta u}{\delta t} = a\ [\ \phi'\ (x + at) - \psi'\ (x - at)\ ].$$

Hence, for $t = O$

$$F(x) = \phi(x) + \psi(x)$$
$$G(x) = a\ [\ \phi'\ (x) - \psi'\ (x)\ ].$$

By integrating the latter expression between $x_o$ and $x$, we get:

$$\phi(x) - \psi(x) = \frac{1}{a}\int_{x_o}^{x} G(x)\,dx$$

*i.e.* for all of $x$:

$$\phi(x) = \frac{1}{2}\left[F(x) + \frac{1}{a}\int_{x_o}^{x} G(x)\,dx\right]$$

$$\psi(x) = \frac{1}{2}\left[F(x) - \frac{1}{a}\int_{x_o}^{x} G(x)\,dx\right]$$

Thus, we obtain a variant of Dalembert's solution:

$$u = \frac{1}{2}\left[F(x+at) + F(x-at) + \frac{1}{2}\int_{x_o}^{x+at} G(x)dx - \frac{1}{a}\int_{x_o}^{x+at} G(x)dx\right] =$$

$$= \frac{1}{2}\left[F(x+at) + F(x-at) + \frac{1}{a}\int_{x-at}^{x+at} G(x)\,dx\right]$$

To obtain the equation applying to the case of a wire fastened at both ends, which is the situation confronting us here, we simply assume for $x=l$ the function $u=o$. We then get:

$$F(l+at) + F(l-at) + \frac{1}{a}\int_{l-at}^{l+at} G(x)\,dx = 0$$

In differentiating with respect to $t$ we get:

$$a\,F'(l+at) - a\,F'(l-at) + G(l+at) + G(l-at) = 0$$

For $F(l) = \phi$, and $t = \phi$, and by changing $t$ into $-t$, we get:

$$a\,F'(l+at) - a\,F'(l-at) - G'(l+at) - G(l-at) = 0$$

*i.e.*:

$$F'(l+at) = F'(l-at)$$
$$G(l+at) = -G(l-at)$$

The equations show that the oscillatory or vibratory rotations of the wire, which is fastened at both ends and is suspended in a homogeneous medium, result from the propagation of two waves continuously circulating within the wire in opposite directions. The function $F(l+at)$ is

even, while the function $G(l+at)$ is odd. The direction in which the wire will rotate depends on which of the two waves $F(l+at)$ or $G(l+at)$, is first to recede at the crucial moment from the fastened end of the wire and to follow the path $2l$. Since the motion is periodic, the oscillatory rotations will maintain themselves at the same amplitude and frequency $f$ and will continue on in the same direction so long as no new external force intervenes. A new external force arises, however, when either the intensity of the electric field is altered or when the electric current $i$ traversing the wire is varied, the latter producing, automatically, a change in strength of the magnetic field H. The whirling action of the fluid medium, in which the rotating wire is suspended, can likewise be expressed with the standard formula

$$\frac{\partial^2 5}{\partial t^2} = a^2 \frac{\partial^2 5}{\partial x^2}$$

the integral solution being: $s = f(x+at) + \omega(x-at)$. For the sake of clarity, it is preferable to consider this whirling action on the part of the medium as deriving from the vibratory rotations of the wire itself. In differentiating the expression $u$, we have:

$$\frac{\partial u}{\partial x} = \frac{\partial \phi}{\partial x}(x+at) + \frac{\partial \psi}{\partial x}(x-at).$$

Or, if we assume $\frac{\partial \phi}{\partial x} = \chi$ and $\frac{\partial \psi}{\partial x} = \omega$, we get the above expression for S. Thus, we have for the full value of $t$ and for $x=1$, $\phi(l+at) = \psi(l-at)$, and for the general expression: $\chi(l+x) = \omega(l-x)$. We would have here a situation analogous to that expressed in the standard equation of telegraphy if we discounted from the latter the electrical leakage and resistance factors.

In the case we are considering, where we are concerned with maintaining the periodicity of the oscillatory rotations in relation to $t$, we should have $u(t+T) = u(t)$, where T is a rotation period independent of $x$. The equation needed is obtained through a formula of the type $\cos nk(x \pm at)$, with $2\pi = KaT$ and $n$ as a whole number. The general solution is yielded by an infinite series:

$$u = \sum_{n=1}^{\infty} \{A_n \cos nk(x+at) + B_n \sin nk(x+at) + C_n \cos nk(x-at) + D_n \sin nk(x-at)\},$$

in which the coefficients A, B, C, and D must satisfy the conditions of convergence. For $x=0$ the equation becomes:

$$\sum_{n=1}^{\infty} \{(A_n + C_n)\cos nkat + (B_n - D_n)\sin nkat\} = 0$$

whereas for $x=1$ we get:

$$\sum_{n=1}^{\infty} (-A_n \sin nkat + B_n \cos nkat) \sin nkl = 0$$

To meet the conditions required for the start and continuation of the oscillatory rotations, either all of the coefficients $A_n$ and $B_n$ must be zero, or else the number $n$ must satisfy the equation $\sin nkl = \phi$. This is equivalent to $nkl = \pi m$, with $m$ as an even number. We must, however, satisfy $nk = \frac{\pi m}{l}$ and $T_m = \frac{2\pi}{nka} = \frac{2l}{ma}$. With $m = 1$ we get those oscillatory rotations with the greatest periods, which are those of the prime harmonic. This period is equal to $2l$ divided by the pulsation of the oscillations, or divided again by the speed of sound. The expression $\cos \frac{m\pi}{l}(x \pm at)$ is periodic, not only with respect to $t$, but also with respect to $x$. This expression remains invariable, inasmuch as $x$ is augmented by the quantity $\lambda$, which satisfies $2\pi l = m\pi\lambda$. But $\lambda$ indicates the length of the wave spreading right and left through the wire which, in turn, delimits that section of the wire affected by the oscillations. The harmonics arise as a function of the propagation of the wave, and the experiment shows that, for the same electric field and same current, or magnetic field, nodes occur along the axis $x$ at the points $o$, $\frac{l}{m}$, $\frac{2l}{m}$, $\frac{3l}{m}$ ..... $\lambda$. (FIGURE 8).

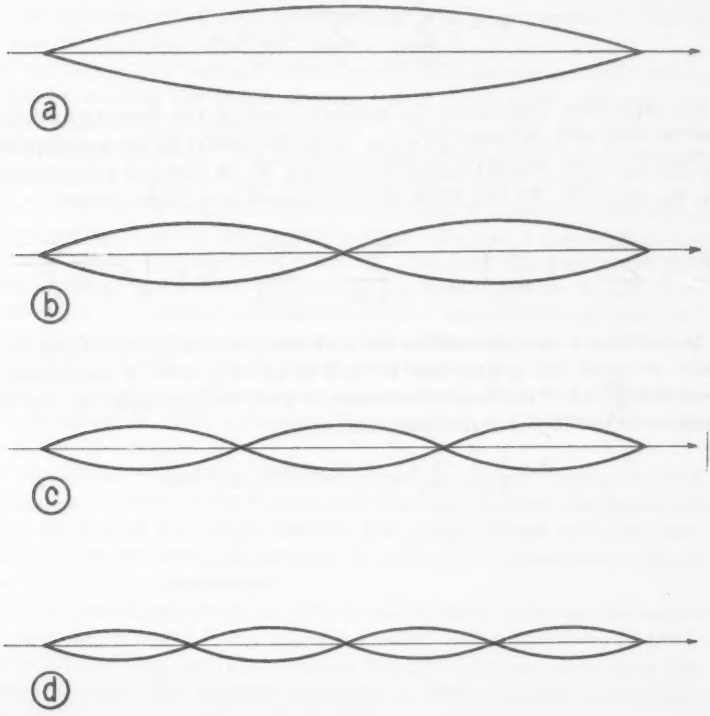


FIGURE 8

The period and wave length of the oscillations are equal, respectively, to the part $m$ of the period and of the length of the prime harmonic, whereas the frequency $f$ becomes $m$ times greater than that of the prime harmonic. The oscillatory rotation of the wire, as a whole, is the sum of an infinite number of such harmonic oscillations. Summation by Fourrier series produces the expression:

$$u = \sum_{m=1}^{\infty} \sin \frac{m\pi x}{l} \left( A_m \cos \frac{mat}{l} + B_m \cos \frac{m\pi at}{l} \right)$$

If we start out with $t = o$ and a definite function $u = f(x)$, we may then write:

$$f(x) = \sum_{m=1}^{\infty} A_m \sin \frac{m\pi x}{l}$$

In the case shown in FIGURES 4 and 5, the wire B is practically stationary. In reality, however, this only seems to be so, for the wire B is definitely oscillating, but its oscillations are so weak that they can barely be perceived. These oscillations are also subject to analysis. Taking the coordinates of Lagrange, we write as the expression of the kinetic energy of a system:

$$W_c = \frac{1}{2} \sum_{2\mu=1}^{n} \sum_{\nu}^{n} a_{\mu\nu} q_\mu' q_\nu'$$

This expression represents the quadratic form of the derivatives relative to time, with the quantities $a_{\mu\nu}$ dependent solely on the coordinates $q_1, q_2, q_3, \ldots q_n$. Since the potential energy $W_p$ is likewise a function of $q_1, q_2, q_3, \ldots q_n$, we may write, by development in a Taylor series:

$$W_p = W_o + \sum_{\nu=1}^{n} q \left( \frac{\partial W}{\partial q} \right) + \frac{1}{2} \sum_{\mu=1}^{n} \sum_{\nu=1}^{n} q_\mu q_\nu \left( \frac{\partial^2 W}{\partial q_\mu q_\nu} \right) + \ldots$$

In oscillatory systems such as we have been discussing here there is a point at which the system may be said to be in a state of equilibrium, such that $\frac{\partial W}{\partial q} = 0$. For the smaller values of $q$ we may disregard the higher numbers in the Taylor series and write simply:

$$W = \frac{1}{2} \sum_{\mu=1}^{n} \sum_{\nu=1}^{n} c_{\mu\nu} q_\mu q_\nu \text{ with } C_{\mu\nu} = C_{\nu\mu}.$$

## *SECTION OF MATHEMATICS AND ENGINEERING*

# A NEW CONSTRUCTION FOR THE CENTER OF CURVATURE*

*By* A. E. Richard de Jonge

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The theory of accelerations, so important to engineering, is intimately connected with that of the curvature of paths described by points whose accelerations are to be determined. When a rigid plane system moves relative to a similar such system which is considered fixed, points, straight lines, and curves of the moving system determine paths, or envelopes, the centers of curvature of which can be found when the center of curvature for the case of a point describing a curve can be found.

Solutions for these problems have been known since 1765 when Leonhard Euler[1] became the first to publish a paper on the shape of gear teeth, in which he gave a construction and formulas for determining the centers of curvature of gear tooth profiles. The paper, written in Latin, became little known.

Felix Savary, of France, probably around 1828, devised a simple formula for determining the center of curvature of point paths. Although his students issued a lithographic copy of it, edited by him, his early death prevented publication of his solution. This formula was first mentioned as the "Savary equation" in a note by Michel Chasles[2] in 1845.

Robert Willis, of England, rediscovered Euler's paper and published a note regarding it in his own paper[3] in 1838. He gave a construction and formulas similar to Euler's for obtaining the center of curvature of gear tooth profiles, which were reprinted in his book.[4] Neither he nor Euler investigated the general relationship of the "quadratic transformation" which Savary's equation expresses. Thus, they missed finding the latter although their formulas can be transformed into it.

The next worker to achieve some success in this field was E. Bobillier who published, in 1870, a theorem[5] from which several constructions of the center of curvature follow.

S. Aronhold, of Germany, presented, in 1872, a paper[6] giving the first systematic treatment of the fundamental theorems of plane kinematics, in which he derived Bobillier's theorem from simpler facts and gave constructions for the center of curvature by means of it, sometimes referred to as Aronhold's constructions.

Wilhelm Schell published, in 1870, a simple construction for the center of curvature by means of the inflection point[7] and, much later, in 1884, Martin Grübler[8] and, in 1910, Theodor Pöschl[9] followed, also using the inflection point. The apparent simplicity of their solutions disappears,

*This paper, illustrated with lantern slides, was the second of two papers presented at a meeting of the Section on April 15, 1955.

because the inflection point, generally not known, must first be determined.

In 1893, Wilhelm Hartmann, of Germany, gave out a new method for obtaining the center of curvature.[10] He used velocity vectors perpendicular to the normal rays. His construction is simple and has the advantage that it can always be carried out even when other methods fail. In addition, it is a powerful projective method (a fact not realized by Hartmann) which gives the quadratic relationship directly. Its disadvantage is the required perpendicularity of the velocity vectors, which makes it sometimes cumbersome to apply.

*New Construction by the Author*

Let the moving rigid system $S_2$, FIGURE 1, be represented by its polode $\Pi_2$,[11] and the fixed system $S_1$ by its polode $\Pi_1$, so that the motion of $S_2$ relative to $S_1$ is represented by the rolling of $\Pi_2$ on $\Pi_1$. Let P be the rotopole (or pole) at which $\Pi_2$ touches $\Pi_1$. The polodes may then be replaced by their osculating circles $\pi_2$ and $\pi_1$. Let $A_2$ be a point of the moving system $S_2$, located on the normal ray $PA_2=n_a$ which makes the angle $\alpha$ with the pole tangent t–t. Since system $S_2$ turns momentarily about P, $A_2$ will, after an infinitesimal motion, come to $A_2'$ and the center $O_2$ of $\pi_2$ to $O_2'$; also the pole P will move to P′ and the normal ray $n_a$ to $P'A_2'=n_a'$. The center of curvature of the path element $A_2A_2'$ lies at the intersection of $n_a'$ and $n_a$ at $A_1$. Let P″ be the projection of P on to $n_a'$. Then $PP''=PP'\sin\alpha$, and with the designations given in FIGURE 1, we get

$$A_2A_2'=r_2d\vartheta;\ O_2O_2'=R_2d\vartheta;\ PP'=ds;\ PP''=r_1d\epsilon=ds\cdot\sin\alpha$$

from which

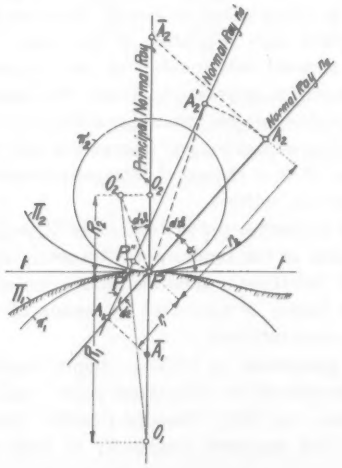


FIGURE 1. General relationship of point paths and their centers of curvature.

$$\frac{A_2A_2'}{PP''} = \frac{r_1+r_2}{r_1} = \frac{r_2 d\vartheta}{ds \cdot \sin\alpha} \quad \text{or} \quad \left(\frac{1}{r_1}+\frac{1}{r_2}\right)\sin\alpha = \frac{e\vartheta}{ds} \tag{1}$$

and also

$$\frac{O_2O_2'}{PP'} = \frac{R_1+R_2}{R_1} = \frac{R_2 d\vartheta}{ds} \quad \text{or} \quad \frac{1}{R_1}+\frac{1}{R_2} = \frac{d\vartheta}{ds} \tag{2}$$

Since $d\vartheta/dt = \omega$ is the angular velocity of $S_2$ relative to $S_1$, and $ds/dt = u$ the pole velocity, *i.e.*, the velocity with which the pole changes its position on the polodes, we get

$$\left(\frac{1}{r_1}+\frac{1}{r_2}\right)\sin\alpha = \frac{1}{R_1}+\frac{1}{R_2} = \frac{\omega}{u} \tag{3}$$

$u/\omega$ is a length which is known as the diameter of the inflection circle, $d_i$. Thus we get finally the complete Euler-Savary equation

$$\left(\frac{1}{r_1}+\frac{1}{r_2}\right)\sin\alpha = \frac{1}{R_1}+\frac{1}{R_2} = \frac{1}{d_i} \tag{4}$$

However $r_1/\sin\alpha = \bar{r}_1 = P\bar{A}_1$, $r_2/\sin\alpha = \bar{r}_2 = P\bar{A}_2$, that is, the radii $r_1$ and $r_2$ are projections of the radii $\bar{r}_1$ and $\bar{r}_2$ on the principal normal ray $O_1O_2$ on to $n_a$, so that we may write

$$\frac{1}{\bar{r}_1}+\frac{1}{\bar{r}_2} = \frac{1}{R_1}+\frac{1}{R_2} = \frac{1}{d_i} \tag{5}$$

In case $R_1$ and $R_2$ lie on the same side of the pole tangent, the + sign changes into a - sign. Relation (5) holds for points on the Ray $O_1O_2$. For any other normal ray, equation (4) holds. Due to $r_1$ and $r_2$ being projections of $\bar{r}_1$ and $\bar{r}_2$, it suffices to find a construction for corresponding points on the principal normal ray only. This is obtained as follows:

During an infinitesimal motion, system $S_2$ rotates about P, FIGURE 2. Thus, $O_2$ moves to $O_2'$ and a point $A_2$ on $O_1O_2$ to $A_2'$. Due to their infinitesimal size, $A_2A_2'$ and $O_2O_2'$ may be regarded as straight line elements perpendicular to $O_1O_2$. On account of the Aronhold-Kennedy theorem, the three poles $O_1$, P, $O_2$ must always lie on a straight line. Thus, $O_1O_2$, the radius of curvature of the path of $O_2$ about $O_1$, may be considered as a third system, or link, connecting $S_1$ at $O_1$ with $S_2$ at $O_2$, as indicated in FIGURE 2. The line $PO_2'$ is arbitrary and determines the end positions of $O_2$ and $A_2$ after the infinitesimal motion. Since polode $\Pi_2$ rolls upon fixed polode $\Pi_1$, P comes into position $P'$. Consequently, the new position of the normal $PA_2$ becomes $P'A_2'$ which meets $O_1O_2$ at $A_1$, the center of curvature of the path described in $S_1$ by $A_2$ of $S_2$.

This configuration of the seven lines $O_1O_2$, $O_2O_2'$, $A_2A_2'$, $PP'$, $PO_2'A_2'$, $O_2'O_1$, and $A_2'P'A_1$ is fundamental. No matter how it may be distorted by projection, the lines remain straight. Thus, if any point Q in $S_1$ be chosen at random, FIGURE 3 (right hand side), and if points P, $O_2$,

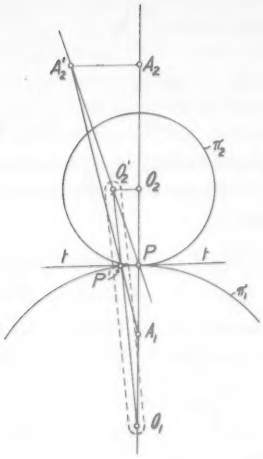


FIGURE 2. Fundamental configuration of lines for determining centers of curvature.

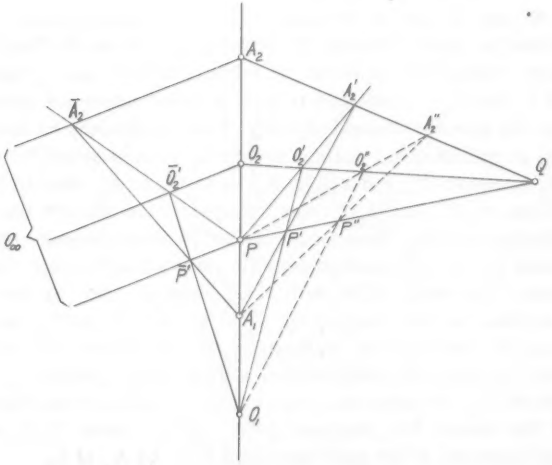


FIGURE 3. Perspective affine and parallel affine constructions of center of curvature.

and $A_2$ be projected from it by three rays, any line $PA_2'$, which represents the arbitrary amount of rotation of $S_2$ about P, determines on the projection rays $O_2Q$, $A_2Q$ and points $O_2'$ and $A_2'$ respectively, and $O_2'O_1$ meets PQ at $P'$ so that $A_2'P'$ will determine $A_1$ on $O_1O_2$, that is, the center of curvature belonging to the curve described by $A_2$.

The proof that $A_1$ is a fixed point on $O_1O_2$ and the center of curvature of the path of $A_2$ can be given as follows:

Draw a second arbitrary line through P intersecting $O_2Q$ in $O_2''$ and $A_2Q$ in $A_2''$. Draw further $O_1O_2''$ giving $P''$ on PQ, and $A_2''P''$ which meets $O_1O_2$ at a certain point $A_1'$. Since the vertices of the triangles $A_2'O_2'P'$ and $A_2''O_2''P''$ are located on three rays meeting at Q, and since two pairs of corresponding sides, $A_2'O_2'$ and $A_2''O_2''$, meet at P, likewise $O_2'O_1$ and $O_2''O_1$ meet at $O_1$, and since P and $O_1$ are fixed points on ray $O_1O_2$, we find, according to Desargues' theorem, that $O_1P$ is the axis of collineation and that the third pair of sides, $A_2'P'$ and $A_2''P''$, must also meet on $O_1P$, that is, at the same point $A_1$ of the original configuration, FIGURE 2, so that $A_1'$ and $A_1$ coincide.

In FIGURE 3 (left hand side), Q has been assumed to be at infinity in any direction. Any random line $P\bar{O}_2'\bar{A}_2'$ meets the parallel rays through $A_2$ and $O_2$ at $A_2'$ and $O_2'$ respectively. Then $\bar{O}_2'O_1$ intersects the parallel through P in $\bar{P}'$, and $\bar{A}_2'\bar{P}'$ produced gives again $A_1$ on $O_1O_2$, the center of curvature for the path of point $A_2$.

It will be seen that the construction, FIGURE 3 (right hand side), which is the perspective affine construction of that shown in FIGURE 2 is the most general construction, and it is of importance, because the axis of collineation does not change with the choice of Q, but coincides always with the principal normal ray for any position of Q. This simplifies finding the center of curvature considerably. FIGURE 3 (left hand side) shows the parallel affine construction of $A_1$.

One special case of this general solution by the author has been known previously, namely, the Hartmann construction. It is also a parallel affine projection of the original configuration of FIGURE 2, but the parallels appear in it as velocity vectors parallel to the pole tangent or perpendicular to $O_1O_2$. Hartmann was not aware of the fact that it is a parallel affine projection of the original configuration, but has used it subconsciously with a projection ratio of 1/dt, as the author has pointed out previously.[12]

Examples of the application of the author's new construction in the parallel affine form were given by him in the discussion of a paper presented before the American Society of Mechanical Engineers, but the paper and discussions[13] have not yet been published.

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## *SECTION OF PSYCHOLOGY*

# THE CONTROL OF HUMAN BEHAVIOR*

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We are seldom willing to admit that we are engaged in controlling the behavior of other people. The commonest techniques of control use force or the threat of force and are objectionable to the controllee and have come to be censured by society. But the condoned techniques of education, persuasion, and moral discourse differ only in the behavioral processes through which they operate and in the minimizing of certain side effects. They are still devices through which one man controls the behavior of another in some measure. Cajolery, seduction, incitement, and the various forms of what biographers call "influence" suggest other techniques.

Familiar rules of thumb in controlling men are embedded in folk wisdom and in many great works of literature. This prescientific technology is rapidly being extended by the scientific study of human behavior (there are those who refuse to admit even the possibility of such a science, but I am speaking here to those who are not only aware of the science but share a deep concern for its consequences). In civilized countries, the more powerful controlling techniques have eventually been contained by a sort of ethical countercontrol, which prevents exploitation by those in a position to use them. There is a real danger, however, that the rapid development of new techniques will outstrip appropriate measures of countercontrol, with devastating results.

We can see how countercontrol originates in the case of force or the threat of force. In primitive literature, the hero is often the man who can whip everyone else in the group in open combat. He controls with the techniques of the bully. The relevant processes have been analyzed in the scientific study of behavior under the headings of avoidance and escape. We see these techniques exemplified today in the government of conquered peoples, in despotic governments of all sorts, by religious agencies which lean heavily on the threat of punishment, by many parents in the control of their children, and by most teachers. The technique is psychologically and biologically harmful to the controllee and, for this reason, has generated countercontrol. The weak are, at least, more numerous, and we now generally hold it to be "wrong" to control through the use of force or the threat of force ( although an impartial observer might not come to this conclusion). Formalized governmental and religious precepts support this containment of the techniques of the bully. The

*This paper was presented at a meeting of the Section on April 18, 1955.

result is called peace– a condition in which men are not permitted to use force in controlling each other.

A later type of popular hero is the cheat, who outwits the strong man by misrepresentation and deceit (in a technical analysis, the relevant processes would be classified under the extinction of conditioned reflexes). But the cheat, eventually, is almost as objectionable as the bully, and ethical control accordingly arises. It is held to be "wrong" to lie, cheat, or cry "Wolf" for one's amusement.

There are techniques which may be as effective as these but may not lead so directly to countercontrol. These techniques are becoming more powerful as their processes are better understood. A few examples follow.

(1) *Emotional conditioning.* Aldous Huxley, in *Brave New World,* describes a perfectly plausible process through which certain inferior types of citizens are permanently dissuaded from wasting time on books and the beauties of nature. Babies are allowed to crawl toward books and flowers but receive electric shocks just as they touch them. The example appears to be borrowed, not from the science of conditioned reflexes, but from certain forms of moral education in which, for example, a child is spanked for taking an interest in parts of his own body. The same principle is used to generate strong reactions of rage and aggression toward the enemy in preparing service men for combat. It is the basis of advertising which shows a product being used by or otherwise associated with pretty girls or admired public figures. The controllee is not likely to revolt against such control, and he may carry the resulting prejudices contentedly to his grave.

(2) *Motivational control.* Crude instances, such as the starving of a whole people so that food may be used to reinforce those who begin to support the government, bring their own eventual containment, but the exploitation of prevailing deprivations may be more subtle and possibly equally effective. The deliberate design of art and literature (as in the movies and "comics") to appeal to people with sadistic tendencies is easily detected, but the subtle design of an automobile so that riding in it is in some measure a sexual experience is not so easily spotted. Neither practice may meet any objection from the people so controlled.

(3) *Positive reinforcement.* Wages, bribes, and tips suggest a classical pattern in which we generate behavior in others through reinforcement or reward. Better ways of using reinforcement in shaping up new behavior and in maintaining the condition called interest, or enthusiasm, have been recently discovered. The reinforcing effect of personal attention and affection is coming to be better understood, especially by clinical psychologists. Lord Chesterfield and Dale Carnegie have recommended the use of feigned attention in influencing people.

(4) *Drugs.* We are entering the age of the chemical control of human behavior. Drugs have been used for this purpose ever since the first man was deliberately made drunk. But better drugs are now available, not only for allaying anxiety but for other purposes of control. Our government would probably not hesitate to use a drug which, taken by servicemen before combat, would eliminate all signs of fear, thus depriving the individual of the protective reflexes which man has acquired through a long process of evolution. In the not-too-distant future, the motivational and emotional conditions of normal daily life will probably be maintained in any desired state through the use of drugs.

(5) *Knowledge of the individual.* Techniques of control can be effective only when certain facts about the controllee are known. Gathering information through eavesdropping, employing spies and informers, opening mail, and wiretapping has, from time to time, come under ethical countercontrol, though the present state of this in our culture is uncertain. Meanwhile, new techniques have been developed. Something like the projective tests of clinical psychology, combined with the technique of of the political trial balloon, might make it possible to discover information about an individual or a whole people, not only without the knowledge of the controllee but with respect to matters of which the controllee himself has no clear understanding.

The doctrine that there is an absolute moral law applicable to all conditions of human life discourages the analysis of controlling practices and obscures our understanding of the need for countercontrol. The methods by which men alter the behavior of other men change, and changing ethical measures are required. A technique need not be immediately objectionable to the controllee to engender countercontrol. The gambler, for instance, is possibly the last person to ask for legal or moral restrictions on gambling enterprises. The alcoholic does not usually advocate the control of alcoholic beverages. Few workers object to being paid, even for kinds of work or according to pay schedules which society proscribes. It is the rare man who objects to the tyranny of the beautiful woman. In all these cases, society appeals to long-term consequences to justify measures of countercontrol. Unfortunately, such consequences do not supply any hard-and-fast rule. We must continue to experiment in cultural design, as nature has already experimented, testing the consequences as we go. We may deal with cultural practices as a whole, as in "Utopian" thinking, or piecemeal by changing one countercontrolling technique at a time. Eventually, the practices which make for the greatest biological and psychological strength of the group will presumably survive, as will the group which adopts them. Survival is not a criterion which we are free to accept or reject, but it is, nevertheless, the one according to which our current decisions will eventual-

ly be tested. It is less clear-cut than some absolute criterion of right and wrong, but it is more reassuring in its recognition of the changing needs of society.

Such an experimental attitude is sometimes criticized by those who want to defend some principle appropriate to an earlier stage of our cultural history. An example is the recent book by Joseph Wood Krutch, *The Measure of Man,* which is in considerable part an attack on my Utopian novel, *Walden Two.* While arguing that the notion of behavioral engineering is ultimately faulty, because man is in some sense free and hence may escape control, Krutch admits that human freedom is under attack and that, if science is not checked, freedom may vanish altogether. Krutch argues that unless we put a stop to the machinations of scientists, "we may never really be able to think again." By freedom, Krutch seems to mean merely a lack of order. The virtues of the prescientific era were the virtues of accident. The great crime of the founder of Walden Two, according to Krutch, was the destruction of the possibility of the happy chance– even such as that which gave rise to the founder himself, before "men's thoughts were controlled with precision." On the same grounds, we might object to the synthetic fibre industry for circumventing the accidental evolutionary processes which produced cotton and wool. If we can arrange better conditions of human life and growth, why should we wait for the happy accident, even if past accidents have brought us to this very point of power?

Krutch's answer is essentially a mystical one: some vague power or faculty has permitted man to transcend his chaotic environment, and this cannot continue to function in less chaotic circumstances. But the existence of such powers or faculties grows more doubtful as man's actual achievements come to be analyzed. Nothing will be lost if science is applied to education or moral discourse. A better way of teaching a child to spell words meets the objection that he is not taught something called "spelling," just as better moral and ethical training meets the objection that the child no longer "has" to be good. In the past, it was natural that some special honor should accrue to the individual who rises above his faulty intellectual and ethical training and is wise and good in spite of it. Men have been at times almost entirely occupied in deciding what is right, intellectually and morally. A world in which education is so successful that one is naturally right in both these senses is criticized because it provides for no heroism in transcending an inadequate environment. One might as well criticize fireproof buildings because the world is thus deprived of brave firemen.

It is easy to object to the control of human behavior by applying the slogans of democracy. But the democratic revolution in government and religion was directed against a certain type of control only. Men were

freed from autocratic rulers employing techniques based upon force or the threat of force. It does not follow that men were thus freed of all control, and it is precisely the other forms of control which we must now learn to contain and to which the pattern of the democratic revolution is inappropriate. The democratic concept of "freedom" is no longer effective in international politics because it has lost its point. All major governments profess to be governing *for* the people, and no government with bear close scrutiny of its actual practices. A new conception of the function and practice of government is needed in dealing with the countercontrol of techniques against which there is no revolt.

Mr. Krutch is justifiably concerned lest a new type of despotism arise which utilizes the more effective techniques of control provided by the science of human behavior. But his suggestion that we deny the possibility of such a science, or that we adandon it, would deprive us of important help in building adequate safeguards against its misuse. Science poses problems, but it also suggests solutions. In contending that the founder of Walden Two could as easily have been a monster, instead of the fairly benevolent figure he seems to be, Krutch misses the point that, in the long run, the strength of any government depends upon the strength of the governed. Under present conditions of competition, it is unlikely that a government can survive which does not govern in the best interests of everyone.

Unless there is some unseen virtue in ignorance, our growing understanding of human behavior will make it all the more feasible to design a world adequate to the needs of men. But we cannot gain this advantage if we are to waste time defending outworn conceptions of human nature, conceptions which have long since served their original purpose of justifying special philosophies of government. A rejection of science at this time, in a desperate attempt to preserve a loved but inaccurate conception of man, would represent an unworthy retreat in man's continuing effort to build a better world.

## *DIVISION OF MYCOLOGY*

### THE OAK WILT FUNGUS, *ENDOCONIDIOPHORA FAGACEARUM**

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Little more than a decade ago, a new wilt disease causing severe damage to oaks in the North Central States was described.[23] Henry[22] studied the fungus pathogen, described it, and named it *Chalara quercina* n. sp. The origin of the fungus is not known, but there is no evidence that it was introduced from a foreign country, as were some of the severe diseases of our native trees.

Within five years after its discovery in Wisconsin, oak wilt came to be recognized as the most important disease of oaks in the northern states. The known oak wilt range now extends from Minnesota to Pennsylvania, southward to North Carolina, and westward to Arkansas and the eastern parts of Kansas and Nebraska.[19]

The first symptoms of the disease in the red oak group are changes in color of leaves, which turn yellow to bronze, usually with a definite green area near the base of the blade. The leaves soon begin to fall and, frequently, only a few remain on the tree. Usually the trees are killed in one season and seldom, if ever, recover from the disease. Trees of the white oak group exhibit somewhat different symptoms. Discoloration of leaves and death of only one side or one branch may be the only external symptoms. Such trees may remain alive for a number of years.

Evidence has been presented[9] showing that the metabolic activity of the fungus stimulates the production of tyloses, quickly reducing the supply of water and causing wilt. It is also possible that other metabolic products found in the culture filtrates, such as toxins and polysaccharides may be involved in the expression of symptoms.[27,43]

Apparently, the fungus exists in the vessels of diseased trees mainly in the form of conidia, as it can be isolated from all vegetative parts of a diseased tree. A number of isolation media, including distilled water, have been used satisfactorily.[12] If the oak wilt fungus is present, it begins to grow after three or four days. Among the agar media, malt extract and potato-glucose agars, commonly used in plant disease studies, were unsatisfactory for quick identification, because the production of endospores was delayed for several days on these media. After trials with numerous combinations of carbon and nitrogen sources, a satisfactory agar medium was developed which contained 3 g. glucose and 0.5 g.

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phenylalanine per liter, plus the necessary salts and micro elements.[2] Thiamine and biotin, while not essential, were added for better growth. The value of this medium lies in the low concentration of sugar and the use of phenylalanine as the sole source of nitrogen. This medium permits only sparse growth of most contaminants as well as the oak wilt fungus and does not prevent the early production of endoconidia, which is an important diagnostic character. As soon as mycelium can be seen growing from the oak chips, the entire Petri dish may be placed on the stage of the compound microscope and examined. On this medium, endospores are usually present after three to five days. If no endospores can be found, positive identification can be made on the basis of the characteristic branched hyphae that frequently have curved tips.[2] These seem to be unique with the oak wilt fungus and are believed to represent abortive conidiophores that, for some reason, remain sterile.

As the mycelium ages, it becomes dark, while the aerial conidial bearing areas remain a lighter tan. Rate of growth, amount of mycelium, and abundance of conidia are greatly affected by the type of medium. On favorable media, certain areas of the mycelium become thickened and mat-like. These areas contain the perithecial initials which are ready for spermatization when cultures are a few days old.

The perithecial stage was first reported by Bretz,[11] who obtained perithecia in agar plates of paired isolates. The fungus was then renamed *Endoconidiophora fagacearum* Bretz.

Soon after the discovery of the perithecial stage, it was found that the single-spore cultures fell into two groups, now called compatibility types *A* and *B*.[25] Each isolate was normally capable of producing both conidia and perithecial initials, but fertile perithecia failed to form unless the cultures were spermatized with conidia of the opposite compatibility type. Thus, the fungus is heterothallic, each single-spore culture being bisexual (hermaphroditic), self-sterile, and cross-fertile.

Cultures on favorable agar media are ready for spermatization when about five to seven days old. Beaks of perithecia begin to push through the mats about 48 hours later, and fully formed perithecia bearing white sticky masses of ascospores at the apex are regularly present three days after spermatization.

Germination of conidia and of ascospores is quite similar. Near optimum temperatures, germination begins within a few hours, and germ tubes are producing conidiophores and secondary endoconidia within 24 hours. Under controlled conditions in the laboratory, both conidia and ascospores germinated within the range of 3° to 33° C.[18] Both at low temperatures and at 30° C., or above, secondary conidia failed to form. Exposures to 36° C. for 34 hours killed all endoconidia and ascospores.

Most of the isolates obtained from oak wilt trees are remarkably uniform in appearance of the dark mycelium. Isolates that have been in

culture for several months sometimes produce lighter colored mutants that retain their ability to produce conidia but are unable to produce perithecia. These are unisexual males.[1] If such mutants exist in nature, it is likely that few survive, for none has been isolated from naturally infected trees.

The inheritance of the male character was easily demonstrated by using the conidia of a light male *A* to spermatize a dark bisexual *B* culture. Single ascospore cultures from this cross segregated into four types: light male *A*, light male *B*, dark bisexual *A*, and dark bisexual *B*. In this mutation, loss of dark pigmentation accompanied loss of femaleness, and these characters were inherited independently of compatibility. Similar mutations to light unisexual males have been incited by exposing spores of normal cultures to ultraviolet rays.

One white mutant that arose in culture proved to be a bisexual albino, like its parent in all respects except for complete lack of pigmentation. Later, another bisexual albino was isolated[7] from a naturally infected oak tree in West Virginia. When an albino culture of type *B* was crossed with a dark *A*, the $F_1$ isolates segregated, as expected, into four groups: albino *A*, albino *B*, dark *A*, and dark *B*. A cross of albino *A* with albino *B* yielded only albino progeny. Perithecia produced by albino cultures are pure white. All albino isolates used in inoculation tests proved to be pathogenic and appear to be quite capable of surviving in nature.

Numerous papers have appeared reporting results of research on various phases of physiology of the oak wilt fungus.[4, 8, 18, 22, 27, 36, 39, 42, 43] The temperature range for growth of mycelium is approximately 8° to 32° C., the optimum being near 20° to 25° C. The upper limit for the production of conidia is near 28° C. Many perithecia are formed between temperatures of 9° and 28° C., with 18° to 25° C. as optimum. A few perithecia have formed at the extremes of 6° and 31° C.[39]

A number of carbon sources are readily utilized for growth in liquid media. Among these are D-glucose, D-fructose, D-mannose, D-galactose, D-zylose, sucrose, maltose, cellobiose, raffinose, L-arabinose, sorbitol, dextrin, and xylan. Some carbon sources that permitted little or no growth were L-sorbose, rhamnose, lactose, melibiose, D-arabinose, and several organic acids.[4, 8, 27, 42]

Nitrogen sources that have been reported as supporting good to fair growth in liquid media are acid hydrolyzed casein, asparagine, aspartic acid, arginine, alanine, glutamic acid, leucine, proline, urea, ornithine, and ammonium salts.[4, 8, 27, 42] Among those which were utilized slowly (or not at all) were phenylalanine, glycine, methionine, valine, tryptophane, isoleucine, cystine, cysteine, histidine, serine, tyrosine, hydroxyproline. Nitrate nitrogen was not utilized.

The optimum pH for rapid growth has been variously reported from 4.0 to 6.5. It is quite probable that this value is greatly influenced by the constituents of the medium.

*E. fagacearum* is capable of growth in a vitamin-free synthetic medium, but most isolates make more rapid early growth when certain vitamins are added. Partial deficiencies for biotin and thiamine have been reported for several isolates,[4, 27] and one isolate was reported as partially deficient for inositol.[8]

Physiological variability is quite evident when several isolates, compared on media differing in vitamin content, were found to differ widely in their ability to synthesize thiamine and biotin. Some isolates produced as much as seven times as much mycelium on thiame and biotin medium as on the control medium. Differences in ability to utilize different nitrogen sources by the same 10 isolates were also evident.

The longevity of the spores of *E. fagacearum* is an important factor to be considered in controlling the disease. In the laboratory, under controlled constant temperature and humidity, it was found that both conidia and ascospores remained viable for a period of about six to eight months at low temperatures (around 10 degrees or lower) and low humidities (50 per cent or lower). At temperatures of 30° C. or higher, and at humidities above 90 per cent, neither conidia nor ascospores lived longer than a few days.[28, 33, 36] Under the most favorable conditions, the ascospores were found to live somewhat longer than the conidia.[33]

The question of degree of pathogenicity of different isolates is a difficult one because of the notorious heterozygous condition of the oaks. Another puzzling question arose when it was found that the great majority of naturally infected trees yielded only the *A* or *B* compatibility type of the fungus.[5, 17] Isolation of both types from the same tree has been reported only a few times.[5, 24] When trees were artificially inoculated with a mixture of spores from dark and albino cultures, it was seldom that both isolates could be recovered from the same diseased tree.[3] The underlying reasons for this intriguing situation are not clear. But it means that the fungus in relatively few naturally infected trees can produce perithecia and ascospores unless the mats formed on the dead trees are first spermatized by spores of the opposite compatibility type, through the action of a vector.[31]

The oak wilt fungus is disseminated in two ways: (1) by the passage of conidia from a diseased tree to one or more neighboring trees by means of pre-existing root grafts; (2) overland for varying distances by means of vectors carrying the fungus spores. It is believed that wind is relatively unimportant in the direct dissemination of spores, since the masses of conidia are usually moist and the ascospores are produced in sticky droplets. Thus, various insects, birds and rodents came under suspicion as possible vectors.

It was not until the fall of 1951 that the sporulating mycelial mats of *E. fagacearum* were found on killed oak wilt trees.[13] Following the death of the tree, the fungus grows from the sapwood into the cambium region and there produces sporulating mats of mycelium.[13, 16, 31, 34, 38] These

mats are capable of producing perithecia when spermatized artificially or naturally by insects carrying conidia of the opposite compatibility type.[6, 13, 16, 31, 38]

Not all oak wilt trees produce mats. They are formed principally during spring and fall, when the conditions of moisture and temperature are more favorable. The first evidence of the mats is the appearance of cracks in the bark, formed by development of a pair of superimposed thick fungus cushions between the bark and wood.[16, 31, 34, 44] These pressure cushions, referred to as "pads" by some authors,[16, 44] function by their growth pressure to separate the bark from the wood,[32] forming large moist chambers in which the sporulating mats develop. One mat develops on the wood surface, while another spreads over the inner surface of the loosened bark.

The cushions are made up of irregularly shaped areas, composed of large, inflated, thin-walled cells,[44] separated by a network of lighter colored lines. The appearances of the contact surfaces has been described as "daedaloid"[31] and as "furrowed and grooved."[16] Such fungus cushions, to our knowledge, have not been described for any other fungus.

The cracks in the bark permit the entrance of fungus-feeding insects and others attracted by the odor of the fungus or the fermented sap. These insects, visiting a mat of one compatibility type, can then carry conidia to mats of the opposite type and initiate the formation of perithecia.[31, 32] Insects and other animals which then visit or feed upon the mycelial mats become thoroughly contaminated with both ascospores and conidia.

In order to complete the disease cycle, spores of the fungus must be introduced into wounds deep enough to reach the sapwood. Some of the insects under suspicion, such as the bark beetles, produce their own wounds but are not attracted to the sporulating mats, while others, such as the Nitidulid beetles, regularly visit the mats and also are attracted to fresh moist wounds.

Successful transmission of the disease has been accomplished experimentally by seven species of Nitidulids,[15, 37] and other insects.[20, 21, 26, 30, 32] Of these insects, the Nitidulids, because of their habits as fungus and sap feeders, seem to be the most important vectors. Torn wounds and blaze type of wounds occurring in the spring and extending to the sapwood seem to be the most susceptible as infection courts. Spores ingested by the insects as well as those carried on the surface of the body remain viable and can serve as inoculum.[29]

The relative ineffectiveness of the vectors is a major reason why the overland spread of oak wilt has been relatively slow as compared to certain other forest tree diseases. This situation, however, may not continue to exist indefinitely. The chance introduction or rapid increase in population of a more efficient vector might well result in a rapid spread of the disease, if effective control measures are not found and applied.

Research on control of oak wilt has been carried on by several states for a number of years and is being continued. Spread through root grafts has been prevented by severing roots around diseased trees to a depth of 30 to 36 inches, or by killing of a ring of trees around an oak wilt tree by means of chemicals. Attempts to check or prevent overland spread have centered primarily around prevention of fungus mat formation, thus eliminating the source of inoculum. In the past, the only certain method was by the complete burning of oak wilt trees soon after they were found. This has been practiced as the regular method of control in some states. While this method is effective, it is time consuming, expensive, difficult, and dangerous in dry seasons. Felling of trees during the summer has been proposed as a method of hastening drying.[10, 16, 35] Recent preliminary experiments have indicated that a simple girdling of oak wilt trees to the heartwood without the use of chemicals, leaving the trees standing, may provide an effective method of preventing mat formation on forest trees.[40]

The comparatively slow overland spread of oak wilt fungus should make it possible to suppress the disease effectively, if adequate control measures are begun promptly and continued as long as the danger lasts. If adequate control measures are not undertaken, there seems to be no reason why this disease in time should not strip our forests of oaks which, now that the chestnut is gone, are our most prevalent valuable timber species.

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## *SECTION OF ANTHROPOLOGY*

# ACCULTURATION AMONG THE TARAHUMARA OF NORTHWEST MEXICO SINCE 1890*

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The Tarahumara are an Indian group numbering approximately 40,000 who inhabit the mountainous regions of southwestern Chihuahua in Mexico. They are subsistence agriculturists who depend primarily upon corn and who raise livestock which is important as a source of manure fertilizer for their fields and of wool for their clothing. They are loosely organized into *pueblos*, each headed by a *gobernador*, and into *rancherías* which are components of the pueblos. There is no tribal organization.

The religion of the Tarahumara is a combination of Catholic and traditional native ritual. Their material culture is relatively simple and consists mainly of objects essential to their survival. Their art is limited and generally rudimentary. Striking aspects of their culture include their great and frequent consumption of *tesguino*, a native corn beer which has important religious, economic, and social significance; their foot races, often lasting two or more days; their habit of dwelling in caves; their respect for native officials; their honesty; and their shyness.

The Indians share their habitat, which is known locally as the Sierra Tarahumara, with 156,000 non-Tarahumaras who, for purposes of simplification, shall be referred to in this paper as Mexicans. The earliest Europeans to come into contact with the Tarahumaras were Jesuit missionaries. They were soon followed by miners, ranchers, and soldiers. Between 1645 and 1690, the Indians actively resisted foreign encroachment upon their lands and several times arose in bloody revolts. Since 1690, they have become more passive and have reacted to Mexican invasion by withdrawing into the more remote sections of the Sierra Tarahumara.

The ethnographic studies of the Tarahumara undertaken by Lumholtz[1] from 1890 to 1895, by Basauri[2] in 1925, and by Bennett and Zingg[3] in 1930 provide a background against which modern students of the Tarahumara may measure the degree of change that has occurred in the culture of these Indians within the past 65 years. Neither of these authors were especially interested in acculturation, and they make but passing reference to the processes and factors involved in the changes that have affected the Tarahumara. Since the period covered by these

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studies is only about 60 years, however, it has been possible to uncover some of these processes and factors from field interviews and from documents relating to the recent history of the state of Chihuahua. Thus a fairly complete, although still tentative, picture of Tarahumara acculturation since the 1890's may be drawn.

The most striking thing about the Tarahumara since the turn of the century is the almost complete absence of change in their culture. The ethnographies of Lumholtz and of Bennett and Zingg are descriptions still applicable in every significant respect to the Tarahumara of today. This fact is particularly astonishing since the Tarahumara have had ample contact with several variants of Mexican culture within the past 60-odd years.

The acculturative forces which have affected the Tarahumara during this span of years have varied, and it is possible to distinguish, on the basis of these variations, three acculturative periods which correspond roughly to three generations of Tarahumaras. The first of these periods lasted from at least 1890 to approximately 1914, and was characterized by (1) considerable pressure on many Tarahumaras to give up their traditional culture; (2) ample opportunity to learn Mexican culture traits; and (3) assimilation of many individual Tarahumaras into Mexican society. The Indians who passed into Mexican society during this period are, or were, the grandparents and great-grandparents of many of the Mexicans living in the Sierra today. The second period lasted from approximately 1914 to approximately 1935 and was marked by (1) decreasing pressure on the Tarahumara to abandon their traditional culture; (2) decreasing opportunity to learn Mexican culture traits; and (3) relatively little assimilation of individual Tarahumaras into Mexican society. The Indians who grew up during this period are the parents of the present-day Tarahumara. The third period has lasted from approximately 1935 until the present. This is a period that has been distinguished by (1) increasing pressure on the Tarahumaras to abandon their traditional culture; (2) increasing opportunity for learning Mexican traits; and (3) little assimilation of individual Tarahumaras into Mexican society.

*Period 1: 1890 to 1914.* During this period, the major influence on the Tarahumaras was the great mining boom which had begun in the 1870's. The silver and gold mines in the great canyons of the Sierra Tarahumara had been worked intermittently and on a small scale by Mexicans since 1630, but it was not until foreign capital and foreign technology were drawn to these mines by the concessions of Porfirio Díaz that their real wealth was plumbed. Under the ownership and directorship of foreign investors and engineers, mining activities in southern Chihuahua expanded rapidly. Mexicans of all categories were attracted to the area and the once somnolent mining camps became bustling, noisy towns. To the extent that it was possible, a regular

pattern of Mexican town life was established in the heart of the wilderness.

The mining boom stimulated the entire economy of the Sierra. Grain, meat, fruit, vegetables, and timber had to be supplied to the mines. Mexican landowners who were already established in the Sierra increased their acreage under crop and enlarged their herds. Poor farmers from other parts of Mexico heard of the fortunes to be made and came to share in the profits. A sizable portion of the Mexican population of the Sierra was engaged in commerce, either in the mining towns or as *arrieros*, itinerant mule-train drivers who traveled from ranch to ranch and from town to town selling cloth, salt, tools, weapons, and buying meat, corn, and other staples.

In these activities, the Tarahumaras participated only indirectly and to their economic loss. Many of the Indians retreated voluntarily, as was their custom, into the less accessible and less fertile areas of the Sierra, but a large number of others were forcibly ejected by the encroaching Mexicans. Lumholtz states that large portions of the most tillable lands in the Sierra were in Mexican hands in the 1890's, and he cites frequent cases of the exploitation of the Tarahumaras by the Mexicans. Among the Indians who remained, many lost their livestock through starvation because Mexican ranchers had appropriated the best pasture lands.

Many of the Tarahumaras who were thus deprived of their means of livelihood were forced to work for Mexicans in order to survive. Many went to the mines to work as laborers, others worked as peons on the Mexican ranches or as servants in the houses of Mexican ranchers and miners. There, the Indians learned Spanish, dressed as the Mexicans did, acquired Mexican tastes and habits. Most of them ceased to participate in Tarahumara culture. When they married—sometimes with Mexicans—they raised their children as Mexicans in an exclusively Mexican milieu. Neither the parents nor the children ever again became Tarahumaras but were absorbed into the Mexican population. There is a fair number of Mexicans in the Sierra Tarahumara today whose parents and grandparents were among the Tarahumaras who had gone to work for the Mexicans during the mining boom. Unfortunately, there are no figures to indicate how many Tarahumaras were thus assimilated by Mexican society but, by all accounts, the number must have been substantial.

By 1914, due to falling silver prices, revolution, and other factors, mining activities began to decline sharply. Except for a brief revival in the 1920's, the Sierra Tarahumara has never regained its former importance as a mining region.

*Period 2: 1914 to 1935*. In contrast with the previous period, the years between 1914 and 1935 were characterized by a relatively peaceful adjustment of populations and cultures in the Sierra. The closing down

of the mines after 1914 deprived most of the inhabitants of the mining towns of work and forced them to seek a living elsewhere. Many of these people established themselves in the Sierra as itinerant merchants or as farmers. This additional influx of farmers to an already crowded land-base might have caused difficulties and further privations for the Tarahumaras except for two factors. For one thing, the cessation of mining activities had brought about a corresponding contraction in the commercial, agricultural, and ranching enterprises of the Sierra. Mexicans who had controlled large areas of land were only too glad to sell parcels of their terrains to land-hungry miners or to employ them as share-croppers. In this way, much of the Mexican population was established in the Sierra without conflict with the Tarahumaras.

The second factor was a reduction in both Tarahumara and Mexican populations due to an epidemic of influenza which was introduced by some of Pancho Villa's marauders in 1918. It is difficult to estimate how many died in this epidemic. There are no official figures and the memories of informants are not too dependable in this matter. Whatever evidence is available, however, points to a considerable loss of life, particularly among the Indians.

The effect of these factors was to reduce Tarahumara-Mexican conflict and contact. Fewer Tarahumaras were compelled to seek their livelihood by working permanently for Mexicans. At the same time, reduced contacts between the two groups provided fewer opportunities for the acculturation of Tarahumara individuals. Under such conditions, the number of Indians assimilated into Mexican society and culture declined considerably.

*Period 3: 1935 to the present*. This is a period that has been marked by increasing conflict over land between Tarahumaras and Mexicans. Population in the Sierra increased by nearly 45,000 between 1930 and 1950.[4] Most of this increase has occurred in the Mexican population. Pueblos which were exclusively Tarahumara settlements in the early 1930's are now settled largely by Mexicans. The expansion of Mexican population during this period has taken place, as it did between 1890 and 1914, at the expense of the Indians, who have been forced back into remote and agriculturally unproductive areas. Attempts by the Mexican government to protect the Indians have been largely unsuccessful due to the difficulties of law enforcement in the isolated Sierra.

The problems of the Tarahumaras have been aggravated in the past 20 years by a succession of droughts and by erosion caused by wasteful agricultural technology and the careless stripping of timber by Mexican lumber companies that began operations in some parts of the Sierra in the early 1940's. The problem of finding sufficient land to produce a crop of corn that will last the year round is an acute one among the Indians today, and probably at least one third of the 40,000 Tarahumaras living in the Sierra are faced with starvation during the summer months

while they are waiting for their new crop of corn to come in.

Because of this increasing economic distress, many Tarahumaras have been forced to seek help from Mexicans and, as a result, are being exposed to Mexican cultural patterns. At the same time, poverty has compelled many of these Indians to curtail their participation in native culture by making it impossible for them to make *tesguino*, the native corn beer, which is of central importance in Tarahumara social, economic, and religious patterns.

Although many Indians work part of the year for local Mexican farmers or in sawmills, these are situations where, because of his limited participation, the Tarahumara individual has little opportunity to acquire non-Tarahumara traits. The most important acculturative forces in the Sierra within the past 20 years have been boarding schools for Tarahumara children. Jesuit missionaries have four such schools in operation with a total enrollment of 165 Tarahumara boys and 152 Tarahumara girls. The Mexican Government has two boarding schools with an enrollment of approximately 160 boys.

Most of the native children enrolled in these schools are there because their families cannot afford to support them, so that a large measure of the success of these organizations in attracting pupils is due to the pressure exerted on the Indian by his poverty. The children enter usually between the ages of five and ten and remain an average of six years. Upon entering, they are given a bath, a haircut, and are dressed in Mexican clothing. The first years are spent in primary school, where they learn Spanish, reading, writing, and rudiments of geography, history, arithmetic, music, and science. Older boys and girls who have finished primary school are given special training: the girls, in domestic arts, such as sewing with the machine, child care, *etc.*; the boys, in agriculture, housebuilding, carpentry, shoemaking, tanning, leatherwork, and barbering.

Unfortunately, neither the government nor the Jesuit schools have records of the children who graduated but, within the past 20 years, it is quite probable that about 2000 Tarahumaras have been exposed for varying periods of time to the teachings of these institutions.

Generally speaking, these graduates have not made an easy adjustment to conditions outside the schools. Almost all of them have returned to the Sierra where they live, for the most part, in precarious economic conditions. Since most came from poor families they had little or no inheritance to which to return. Except in the case of some of the girls who can work as domestics in Mexican homes, the skills acquired by the Indians in the schools have no economic value because there is no market for them in the Sierra. Furthermore, certain traditional Tarahumara skills that do have economic value for the Indians, such as weaving, basketry, ceramics, and working with the axe, were not taught in the schools.

The social adjustment of the graduates has been no better than the economic one. On the one hand, since these individuals were raised in a Mexican milieu, they feel ill-at-ease among less acculturated Indians and tend to shun them. In addition, the poverty of these graduates and their consequent inability to make *tesguino* intensify their break with traditional Tarahumara culture. On the other hand, the Mexicans in the Sierra see to it that the Tarahumara, both economically and socially, is kept in an inferior position. The result of these conditions is a growing class of marginal individuals who find themselves incapable of participating fully in either of the societies and cultures present in the Sierra.

Both the Mexican Government and the Jesuit missionaries have attempted to ease the adjustment of the boarding-school graduates by providing jobs and housing for a small number of them in several small colonies established in mission and government centers. But these colonies depend, for their existence, on the economic support of the sponsoring institutions and thereby merely serve to point up the inability of the boarding-school graduates to make an independent adjustment.

This third period in Tarahumara acculturation has been similar to the first in that it has been marked by Tarahumara-Mexican conflict, with the consequent detaching of individual Tarahumaras from native culture and the exposure of these detached individuals to Mexican culture. The two periods have differed in that, during the first period, the acculturating Tarahumara acquired Mexican traits by participating in Mexican mining-town culture while, in the more recent period, he has acquired them in the boarding schools. The most significant difference between the two periods, however, has been the fact that where, at the turn of the century, the acculturated Indian found social and cultural conditions to which he could adjust, in recent years he has failed to find such conditions.

A review of what has been happening to the Tarahumara in the past 65 years shows clearly one of the connections between *assimilation* and *culture change*. Linton[5] has pointed out that one of the processes involved in culture change is the dissemination of new traits to the rest of the population by innovators, *i.e.*, by those who are the first to accept new traits. Between 1890 and recently, this process of dissemination has been absent in Tarahumara acculturation. One of the reasons for this is that, although many Tarahumara individuals have acquired new traits, most of these acculturated individuals have ceased their participation in Tarahumara culture and have been assimilated into Mexican society and culture. In Linton's sense, there have been Tarahumara innovators, but few or no disseminators.

Today, a somewhat different situation obtains. Due primarily to the activities of the boarding schools, there is an increasing number of acculturated Tarahumaras but there is no Mexican society in the Sierra that can assimilate them. As a result, they are being compelled to

remain participants in Tarahumara culture. Because of this, and as their number increases in proportion to the total Tarahumara population, it is to be expected that they will begin to function as disseminators of the new traits they have acquired in the boarding schools. Of course, the mere presence of innovators in a group does not constitute a sufficient condition for culture change—there are many other factors involved, such as the nature and degree of contact between acculturated and unacculturated individuals and the compatibility of the new traits with existing patterns—but it is a necessary condition.

It appears, therefore, that there is an inverse relationship between assimilation and culture change. The more the process of assimilation occurs and absorbs potential disseminators of new traits, the less chance there is for a change in culture to take place. This, of course, does not refer to the culture into which the acculturated individuals are being assimilated.

## *References*

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## *CONFERENCE HELD*

## *SECTION OF ANTHROPOLOGY*

## DYNAMIC ANTHROPOMETRY

***Friday, April 15 and***
***Saturday, April 16, 1955***

*Conference Chairman:* Earl W. Count
Hamilton College, Clinton, New York

### FRIDAY, APRIL 15, 1955

*Session Chairman:* Loren C. Eiseley
University of Pennsylvania, Philadelphia, Pa.

**9:00 A.M. –**
Statement of General Objectives – Earl W. Count.

"Organic Form as Determined by Function" – N. Rashevsky, University of Chicago, Chicago, Ill.

"Entropy and Growth of an Organism" – L. Brillouin, Columbia University, New York, N. Y.

"D'Arcy Thompson's Mathematical Transformations and the Analysis of Growth" – Oscar W. Richards, American Optical Company, Southbridge, Mass.

General Discussion.

*Session Chairman:* William W. Howells
Harvard University, Boston, Mass.

**2:00 P.M. –**
"An Experimental Statistician Looks at Anthropometry" – Donald Mainland, New York University, New York.

"Allometry and Anthropometry" – A. H. Hersh, Western Reserve University, Cleveland, Ohio.

"The Role of Anthropometry in the Study of Body Composition: Toward a Synthesis of Methods" – Josef Brožek, University of Minnesota, Minneapolis, Minn.

"Toward an Anthropometry of the Brain" – Gerhardt von Bonin, University of Illinois, Chicago, Illinois.

General Discussion.

## SATURDAY, APRIL 16, 1955

*Session Chairman:* William W. Greulich
Stanford University, Stanford, Calif.

**9:00 A.M. –**

"Longitudinal Anthropometric Data in the Study of Individual Growth Patterns" – Howard V. Meredith, Medical School, State University of Iowa, Iowa City, Iowa.

"Relative Growth of the Human Skeleton, Cranial and Post-cranial" – Melvin L. Moss, Columbia University, New York, N. Y.

"Anthropometry in the Field of Developmental Human Biology" – Stanley M. Garn, The Fels Research Institute, Yellow Springs, Ohio.

"Body Dynamics and Dynamic Anthropometry" – Herbert Elftman, Columbia University, New York, N. Y.

General Discussion.

*Session Chairman:* Wilton M. Krogman
University of Pennsylvania Medical School
Philadelphia, Pa.

**2:00 P.M. –**

"Body Links and Joint Centers as a Functional Basis for Analysis of Activity Patterns" – Wilfrid T. Dempster, University of Michigan, Ann Arbor, Mich.

"Studies in Human Biomechanics" – F. Gaynor Evans, Department of Anatomy, Wayne University College of Medicine, Detroit, Michigan.

"Some Contributions of Anthropometry to Human Engineering" – H. T. E. Hertzberg, Aero Medical Laboratory, Yellow Springs, Ohio.

"Anthropometric Data in the Design of Anthropometric Test Dummies" – Lawrence E. Abt, Beth Israel Hospital, New York, N. Y.

General Discussion.

Summary Conclusions.

# *NEW MEMBERS*

## *Elected April 28, 1955*

### *LIFE MEMBERSHIP*

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